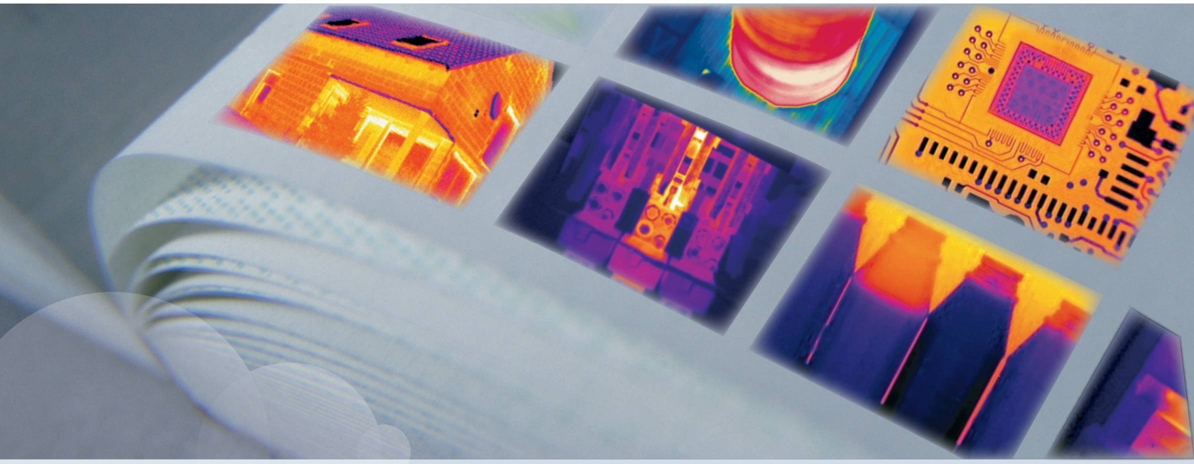
User’s manual



ThermaCAM™ Researcher Professional

Professional edition. Version 2.9

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ThermaCAM™ Researcher Professional

User's manual

License number:

Publ. No. T559009 Rev. a387 – ENGLISH (EN) – August 28, 2009

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Table of contents

1 Notice to user

Typographical conventions

This manual uses the following typographical conventions:

- **Semibold** is used for menu names, menu commands and labels, and buttons in dialog boxes.
- *Italic* is used for important information.
- `Monospace` is used for code samples.
- UPPER CASE is used for names on keys and buttons.

User-to-user forums

Exchange ideas, problems, and infrared solutions with fellow thermographers around the world in our user-to-user forums. To go to the forums, visit:

http://www.infraredtraining.com/community/boards/

Additional license information

This software is sold under a single user license. This license permits the user to install and use the software on any compatible computer provided the software is used on only one computer at a time. One (1) back-up copy of the software may also be made for archive purposes.

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2 Customer help

General

For customer help, visit:

http://flir.custhelp.com

Submitting a question

To submit a question to the customer help team, you must be a registered user. It only takes a few minutes to register online. If you only want to search the knowledgebase for existing questions and answers, you do not need to be a registered user.

When you want to submit a question, make sure that you have the following information to hand:

- The camera model
- The camera serial number
- The communication protocol, or method, between the camera and your PC (for example, HDMI, Ethernet, USB™, or FireWire™)
- Operating system on your PC
- Microsoft® Office version
- Full name, publication number, and revision number of the manual

Downloads

On the customer help site you can also download the following:

- Firmware updates for your infrared camera
- Program updates for your PC software
- User documentation
- Application stories
- Technical publications

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3 Welcome!

Thank you for choosing ThermaCAM™ Researcher Professional!

This is the operator's manual of ThermaCAM™ Researcher Professional. We are convinced that this program will be a useful tool when you explore the fascinating world of infrared imaging and measurements.

ThermaCAM™ Researcher Professional supports six hardware configurations:

- Standard Ethernet
- Gigabit Ethernet
- FireWire
- PC-Card
- Parallel
- IRFlashLink

The interfaces are used for several types of cameras. The manual, together with the Camera Connections manual, covers all configurations and all cameras. Make sure that the information you read is about the right camera with the right type of camera interface.In the manual, you should be able to find detailed answers to these three types of questions:

- What kind of hardware and software is used? How is it to be installed?
- What is the software and thermography like, in general?
- How should I use ThermaCAM™ Researcher Professional, to get some particular result?

Since this is more like a reference manual than a tutorial, there will be rather detailed answers to those questions. It means that you probably only will study the manual in parts from time to time.

If you need the manual, but cannot find it, you can rely on that the same information is available as the help text of the program.

3.1 New features in ThermaCAM™ Researcher Professional 2.9

ThermaCAM™ Researcher Professional 2.9 has a number of changes mainly regarding the following:

- Text comments in ThermaCAM™ SC640 were previously ignored. This behavior has been corrected.
- Connection to ThermoVision™ A320 and A320G is now provided.
- Better handling of low battery/hibernate during recordings.

- The subtraction preview did not always display the correct images.
- Support for Windows Vista

4 Installation

4.1 Installation instructions

The ThermaCAM™ Researcher Professional CD-ROM contains all software manufactured by FLIR Systems AB that you need in order to run ThermaCAM™ Researcher Professional with:

- a FireWire Interface
- a PC-Card® Interface
- an IC2-DIG16 frame grabber
- an IRFlashLink board
- a Gigabit Ethernet interface
- a standard Ethernet interface

4

For the IRFlashLink board, you also need a CD-ROM from its manufacturer.

The installation procedures for these configurations differ, so please follow only the instructions that are appropriate for your particular configuration.

The installations are two-step procedures. It is recommended that you install ThermaCAM™ Researcher Professional first, before the installing the camera interface device drivers, but that order is only required for Windows 98.

4.1.1 Requirements

ThermaCAM™ Researcher Professional runs on Windows 2000, Windows XP (32-bit edition), and Windows Vista (32-bit edition). ThermaCAM™ Researcher Professional might also run on Windows 98/ME, Windows NT 4.0 (service pack 3 or higher), but full functionality and performance cannot be expected.

The following exceptions exist:

- The FireWire interface for image frame grabbing, as well as ThermoVision™ A320, require Direct-X 8.1 (or higher). Since the FireWire technology is quite new to Windows, we recommend that the most recent service packs and Windows updates are installed on Windows 2000 and Windows XP. Updates from the computer manufacturer web site may also be required.
- There is no support for the FireWire interface on Windows NT 4.0, and Windows 98 (first edition)
- The IRFlashLink Frame Grabber requires Windows 2000, XP or NT 4
- Maximum speed image recording (burst recording) is only possible if the speed of the hard disk I/O is sufficient. If you intend to use IDE Ultra DMA 100 disks, you have to have at least Windows XP or service pack 2 of Windows 2000 to make them work.

- If you install a PC-Card® interface on Windows NT 4.0, you will also need the CardWare software (version 6.00.007 or higher) from Unicore Software Inc. (www.unicore.com)
- The Gigabit Ethernet interface requires a network interface compatible with the Intel 82540 network chip for optimum performance (Intel 82541 and 82546 are also acceptable).
- The PC-Card®, IC2-DIG16 and IRFlashLink interfaces cannot be combined with usage of the ThermoVision™ SC4000/SC6000/A320/A320G cameras and cannot be installed on Windows Vista.
- For the Gigabit Ethernet interface, Windows 2000, XP, or Vista is required

4.1.2 Installing ThermaCAM™ Researcher Professional

We recommend that you first close all applications running on your computer (except for antivirus and firewall software).

If you have Windows NT 4.0, 2000 or XP, please log in as the Administrator during the installations.

4.1.2.1 Installation of the application software

ThermaCAM™ Researcher Professional is installed by an installation utility program. It will guide you through the installation steps, and do most of the work. Just insert the CD-ROM and choose to start the installation of ThermaCAM™ Researcher Professional from the installation window that appears.

During the installation, you will be asked to type in the license number. Your license number is unique, and can be found on the first page of the manual.

The directory structure of ThermaCAM™ Researcher Professional is pre-set. The only adaptation you can make to it is to change the name of the directory in which the program is installed.

You will be asked about which type of cameras you intend to use, in order to avoid installation of too many different drivers.

When the installation finishes, you may have to restart your computer.

After this installation, you will be able to start ThermaCAM™ Researcher Professional from the Programs entry of the Start button menu.

4.1.2.2 Installation of the Direct-X software

With the FireWire interface, and with the ThermoVision™ A320 camera, Direct-X 8.1 (or higher) is required. In that case, the ThermaCAM™ Researcher Professional installation looks for Direct-X, checks its version and tells you to install it if needed. The installation window offers you the possibility to install Direct-X 8.1 from the CD-ROM.

4.1.2.3 Installation of the camera interface driver software

When the application installation is finished, you will be reminded about the camera interface driver software installation. You will not be able to connect to the camera, only to work with images stored on disk, until you have installed this software.

The plug-and-play FLIR Systems camera interface drivers can be found on the ThermaCAM™ Researcher Professional CD-ROM, as well as in the directory C:\Program Files\FLIR Systems\Device Drivers, to which the ThermaCAM™ Researcher Professional installation program copies them (except for the device drivers for the eBus Driver Suite). When you install your device drivers, you can find all necessary FLIR Systems files there.

4.1.2.4 Installation of the eBus Driver Suite

NOTE: Before you try this, make sure that your computer is fully updated by Windows® Update.

To take full advantage of an Intel 82540 Gigabit Ethernet Network Adapter you need to install and activate the eBus Driver Suite, available on the ThermaCAM™ Researcher Professional CD-ROM in the eBus folder. The installation just copies the drivers to your hard disk drive. To activate a particular driver, you have to run a program from the Start menu. Select **Pleora Technologies, Inc.**, **eBus Driver Suite** and **Driver Installation Tool**. Pick the right Ethernet adapter and select **Configure**. Select the optimum eBus driver and click **Finish**.

You may also have to click **Update** to update the drivers as well.

SEE ALSO: For information about how to install the device drivers for the FireWire interface, as well as other device drivers, see:

- 8 – FireWire™ configuration on page 81
- Camera connections (Publ. No. T559010)

4.2 Where do the installed files go?

On all Windows systems, the installation program builds a new directory tree, normally at C:\Program Files\ThermaCAM™ Researcher Professional\, containing the following files:

ThermaCAM™ Researcher Professional\	Executable files, help file, OLE type library.
…\Examples	Sample Microsoft® Excel files with their session files
…\Images	Sample image files
…\Palettes	Palette files (scale color definitions)
...\Binaries	dll:s and controls related to the Indigo camera

The installation also adds some executable files into the main Windows directories, and a number of device drivers to the C:\Program files\FLIR Systems\Device drivers directory.

On Windows 2000, Windows XP, and Windows Vista, which are multi user systems, only administrator users may create and update files in the common **Program Files** directory. Ordinary users are not permitted to do that. Ordinary users have a place of their own where they can keep the data files of their programs. It is called **My Documents**.

On Windows 2000, Windows XP, and Windows Vista, the \Examples, \Images and \Palettes files are copied to a ThermaCAM™ Researcher Professional subdirectory of the **My Documents** directory of each user when he, or she, starts to use the software. Then each user easily can modify them separately.

NOTE: These **My Document** files are not removed when you remove the program.

5 About the program

5.1 *Basic principles for ThermaCAM™ Researcher Professional*

The main purpose of this program is to deal with live IR images arriving through a camera interface. It can also receive IR images from other media, such as SD Memory Cards from ThermaCAM™ cameras.

The program can make studies on high/medium/slow speed thermal events depending on the hardware configuration. It can show IR images, record them on disk and analyse them afterwards during their replay. It can provide measurement result values directly from the live stream of images too, but only for the images you decide not to record.

The measurements are made with the following analysis tools: isotherm, spotmeter, area and line. The results produced by these tools can be displayed within the IR image, in the profile window, in the histogram window, in the result table window, or in the plot window. Formulas can be applied to the results.

The program uses a set of predefined screen layouts, one for each type of work that you could have in mind.

You can also extract information from ThermaCAM™ Researcher Professional by using OLE (which is an automatic way of transferring information between programs running under Windows) to bring the information into for example Microsoft® Excel or Microsoft® Word. The IR image can be transferred in the same way. The clipboard functions **Copy** and **Paste** are used for this purpose.

Several copies of ThermaCAM™ Researcher Professional can run at the same time, but only one at a time can be connected to the same camera.

5.2 *Working with ThermaCAM™ Researcher Professional*

A typical user of ThermaCAM™ Researcher Professional would probably install it both on a laptop computer, which easily can be brought along to the site where the data is to be collected, and on a stationary computer connected to a network with printers and disks on it.

At the site, the user would set up the camera, connect it to the computer and start recording.

Some users will record images, lots of images, and go back home in order to study them. Others will immediately make measurements and simply record a few values on paper or in a spreadsheet and forget about the images on which they are based.

Some users are satisfied with the temperature measurements as such, others want mathematical functions of temperature or to correlate the measurements to something else, like pressure or vibration or the incidence of some event.

Being careful when setting up the camera will normally improve the measurement results. This could mean measuring the object parameters carefully, avoiding creating images containing reflections from strong heat (or cold) sources in the neighbourhood, using a spectral IR-filter which is appropriate for the application and so on.

Before studying the recorded images, one has to pick out and examine the really interesting ones. Then one normally finds that something has to be done to them before the actual analysis begins. The emissivity factor might be wrong, or the temperature scale limits or the analysis tool is missing or whatever. The images recorded by ThermaCAM™ Researcher Professional do not contain any analysis; it has to be added on.

In this preparatory step, the user will scan through all the images, noting the interesting ones, grouping them and preparing them for analysis. This involves either applying a correction to each individual image, actually changing the file, or using a standard correction replacing some parameter of the images but not changing the images themselves.

The standard correction is, in this program, often indicated by the word **lock**. It is possible to lock the temperature scale, lock the object parameters the analysis functions and lock the zoom factor. This means for instance that you can apply your favourite temperature scale to an image by locking the scale and setting it to your favourite values. The current image, and the ones that follow, will be presented with your favourite scale despite having another scale stored inside them. When you unlock the scale, the original scale of the image will reappear.

The actual analysis involves playing through the images once more, taking values from the analysis tools of the images and comparing them to what was expected.

The analysis might be preceded by a conversion of some kind, such as image subtraction.

The results of the study might become an important part of a research report, a graph or a set of images supporting some vital conclusion.

5.3 List of current image files

When you store images with ThermaCAM™ Researcher Professional you can either store them one by one, giving each image a characteristic file name, or store them as a sequence thus indicating that they have something in common.

Such a sequence of IR images is recorded in an image directory either as separate files or in a single file. This is a decision you take when you set the recording parameters.

When the recording is finished, the sequence recording function assumes that you would like to replay and analyse the new images. It creates a list of the image files concerned and keeps it until the next recording.

This list, a group of names of image files in the same directory, is what still keeps the sequence together. You may change the list at will, adding or removing file names, but then the sequence concept is lost.

You can actually group any images you like into a fake sequence. The only restriction is that they have to be stored in the same directory on the disk. You do not have to include all the images of the directory.

Single file image recordings are normally quite large. ThermaCAM™ Researcher Professional has functions that will let you edit these files. Then you are supposed to first open all images and then mark the images to be removed or copied as a selection.

5.4 Image directory

All the images of the same recording are placed in the same directory on disk. We call it *the image directory*. The full path name of the image directory is displayed in the program title bar. You should set it when you determine the conditions for image recording (or when you create a new image list out of pre-recorded images).

5.5 Session files

You often need to be able to recreate particular situations (such as an experiment) during your work. ThermaCAM™ Researcher Professional uses session files for this purpose. It stores for example the names of the currently open images in its session files. They do however not contain the images themselves. You will notice this, if you save your session while looking at a frozen live image. When the session is recreated, the former live image is gone.

The full path name of the image directory is also stored in the session file.

If you move the images (or try to reach them from another computer in which the image directory has another path), you will have to correct this path in order to be able to see the images again.

Normally, every recording of images would be ended with the creation of a session file. It would usually be placed in the same directory as the images, but that is not a requirement. Later, when you start analysing the images, you pick up the session file,

add analysis tools or other settings to it and save it to disk again. The session files do not contain any images or analysis results, only file names and information about the program settings.

You may select a session file to become the default session. This means that every time you start ThermaCAM™ Researcher Professional or order a brand new session, the default session settings and images will be fetched. The **Set Default Session** command is in the **File** menu.

Should you wish to avoid reading the default session, press SHIFT while ThermaCAM™ Researcher Professional starts.

You deselect the default session by opening the default settings dialog box and clicking the **Cancel** button.

5.6 Program screen layout

10426603;a3

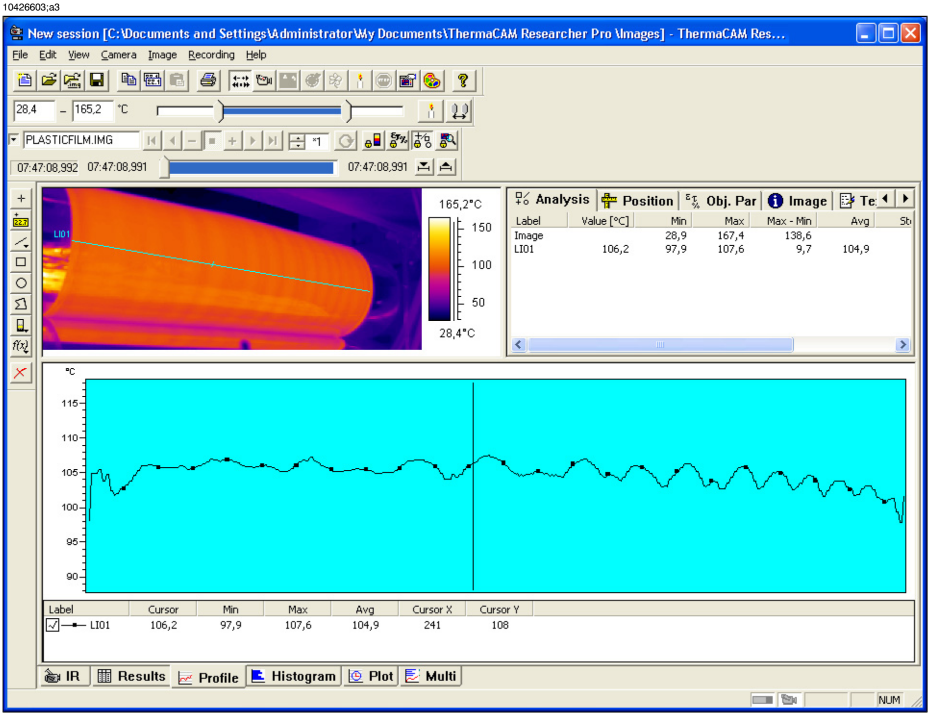

Figure 5.1 Main window

There are several layout options available. These are controlled by tabs in the bottom part of the ThermaCAM™ Researcher Professional window. You can see combinations of the IR image, the profile, the histogram, the plot and the result table windows. All tabs have an IR image with a temperature scale in the top left corner.

You cannot reposition the windows within the tabs, but you can catch and move the splitter bars that separate the windows, thus increasing or decreasing the relative size of each of the windows.

You can copy the whole program window to the clipboard by pressing the ALT + PRINTSCRN key buttons. You can also save the current tab as a bitmap by the command **Save Tab As** in the **File** menu

The program can only show one image at a time. On the image, the analysis tools are displayed. The results of the analysis tools can be displayed in the histogram, profile, plot or result table window.

The main layout of the program is pretty much like any other Windows program. On the top line of the program window, there is a title containing a session name, the image directory and the three buttons, minimise, maximise and close, from left to right. The same functions are available on the right mouse button menu of the top line.

Below the top line, there is a set of drop-down menus by which you can select functions related to session/image filing (**File**), the clipboard (**Edit**), the screen layout (**View**), the camera (**Camera**), the display and analysis of the image (**Image**) and the recording/playback of images (**Recording**).

There is also a large number of toolbar buttons. There are toolbar buttons for almost every function of the program. Every toolbar button has a short yellow description that will pop up if you hold the mouse cursor still for a while on top of it.

The toolbars are normally docked to the borders of the program window, but can be undocked and placed anywhere on the screen. Just double-click on them.

There is also a floating camera control panel that can not be docked to the program window. Use it to change the camera settings and affect how the live image is generated.

At the bottom of the program window, on the status line, a more detailed description of the menu items and tool bar buttons will be shown while you sweep through menus and over the toolbar buttons by the mouse cursor. Towards the right of this status line, there are indicators of the **Interface** status and the **Camera** status as well as keyboard indicators for Caps Lock and Num Lock. You can click on the **Interface** and **Camera** indicators and get further information about the interface and the camera.

5.6.1 Standard toolbar

10417703;a2

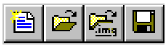

Figure 5.2 Standard toolbar

From left to right:

- Create a new session
- Open an existing session
- Open/add images to the current session
- Save the current session using the current name

10417803;a2

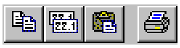

Figure 5.3 Standard toolbar, continued

From left to right:

- Copy the session file and the current image to the clipboard
- Copy values, such as analysis results, as text to the clipboard
- Paste a copied session into ThermaCAM™ Researcher Professional. The name of the session is not pasted.
- Print the current image

10417903;a2

Figure 5.4 Standard toolbar, continued

From left to right:

- Select disk images as the image source
- Select the live camera as the image source.
- Move the camera focus towards infinity
- Autofocus the camera
- Move the camera focus towards the lens
- Switch on the function automatic adjustment of the image scale
- Freeze the live stream of images from the camera
- Bring up the image settings dialog box
- Bring up the palette selection dialog box

10418003;a2

Figure 5.5 Standard toolbar, continued

- Bring help from the manual

5.6.2 Play images toolbar

10418103;a2

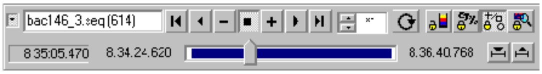

Figure 5.6 **Play images** toolbar

Top row:

- Show second row: ON/OFF
- Name of the current image. You may type a name or number in this field.
- 7 VCR style playback buttons. Stop in the middle.
- A control by which the replay rate is controlled
  - ***1** means full speed from disk
  - ***2** means twice full disk speed (i.e. every other image is not shown)
  - ÷**2** means half full speed
- Auto rewind button
- **Lock temperature scale** button
- **Lock object parameters** button
- **Lock analysis tools** button
- **Lock zoom factor** button

The **Lock** buttons will, when pressed, let you keep the same temperature scale / object parameters / analysis tools / zoom factor for all images being replayed, regardless of what is stored inside the images. When you depress these buttons, the information of the images will be used instead.

Second row:

- Current image time/frame/trig count
- First image time/frame/trig count
- Slider. Move fast within your image sequence. The first image is to the left.
- Last image time/frame/trig count. The time/frame/trig count field depends on the **Presentation** selection in **Replay Settings** in the **Recording** menu. It is either absolute image time, relative time to first frame, frame number or trig count.
- Set selection start
- Set selection end

Start is always to the left of **End**. The slider will highlight the selected area within the sequence with a blue color.

5

5.6.3 Recording toolbar

10418203;a2

Figure 5.7 **Recording** toolbar

Left to right:

- Name of the next image to be recorded
- Start button
- Start condition field
- Record one image button
- Recording condition field
- Pause button
- Stop button
- Stop recording condition field
- Bring up the recording conditions dialog box
- Replay the recorded sequence in a separate copy of ThermaCAM™ Researcher Professional

5.6.4 Image dir toolbar

10418303;a1

Figure 5.8 **Image dir** toolbar

- The image directory. You may edit this field to change it.
- Browse existing directories

5.6.5 Analysis toolbar

The following analysis tools exist (left to right):

10418403;a1

Figure 5.9 **Analysis** toolbar

From left to right:

- Spot meter
- Flying spot meter. Uses the mouse cursor.
- Line, with cursor
- Box area
- Circle area
- Polygon area
- Isotherm (above, below, interval)
- Formulas

- Removal tool

5.6.6 Scaling toolbar

10418503;a2

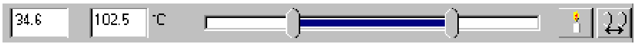

Figure 5.10 Scaling toolbar

From left to right:

- Scale max temperature field. Editable.
- Scale min temperature field. Editable.
- Current measurement unit indicator
- Slider for the scale max and min temperature. Drag with mouse. **Min** is to the left.
- Automatic adjustment of the scale to the image: ON/OFF
- Lock span: ON/OFF. Changes apply only to the level.

The highlighted region in the sliders indicates the span of temperatures in the image. By selecting **Auto Adjust**, you will place the slider markers close to the ends of the highlighted area, but still inside it. A small part of the span is thus wasted.

5.7 Shortcut keys

Menu selections can be made from the keyboard. Press Alt + the key indicated on the menu line by an underscore. This brings up the menu. Then press the key indicated in the menu by an underscore to select that item.

In addition to the tool bars, there are a number of shortcut keys on the keyboard by which important functions can be reached:

Key combination	Explanation
ALT + F4	Exit
CTRL + A	Auto adjust image
CTRL + C	Copy session and image
CTRL + D	Play recorded sequence
CTRL + F	Freeze/Unfreeze image
CTRL + F2	Step backwards
CTRL + F4	Step forwards
CTRL + I	Open disk images
CTRL + L	Show live images
CTRL + N	New session

Key combination	Explanation
CTRL + O	Open session
CTRL + P	Print
CTRL + PAGE UP/DOWN	Changes max scale temperature
CTRL + R	Autorewind mode on/off
CTRL + S	Save session
CTRL + SHIFT + F2	Set selection start (within sequence)
CTRL + SHIFT + F4	Set selection end (within sequence)
CTRL + SHIFT + TAB	Previous main tab
CTRL + T	Show the camera control
CTRL + TAB	Next main tab
CTRL + V	Paste session
END	Last disk image
F2	Play backwards
F3	Stop playing
F4	Play forwards
F5	Image recording keyboard trig
F8	Freeze/Unfreeze image
F9	Camera autofocus
F11, F12	Camera focus
HOME	First disk image
PAGE UP/DOWN	Changes min scale temperature
SHIFT + F2	Fast backwards
SHIFT + F3	Stop
SHIFT + F4	Fast forwards

NOTE: Some shortcuts do not work in OLE embedded mode.

6 Tutorials

6.1 *How to begin using a camera*

We recommend that you connect the cables and start the camera before starting the ThermaCAM™ Researcher Professional program. The first time you run ThermaCAM™ Researcher Professional, you will have to indicate which type of camera you have got and how it is connected physically. This dialog box automatically shows up:

10418603;a5

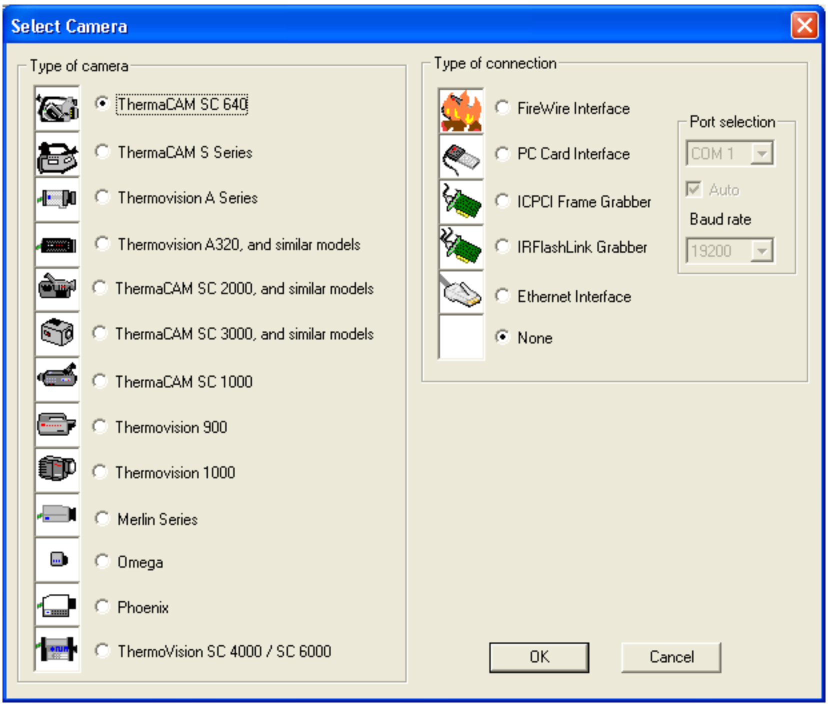

Figure 6.1 Select camera dialog box

You do have to bring up this dialog box yourself (from the **Camera** menu), if you want to change the selected camera type or connection.

6.2 How to connect and control the camera

SEE ALSO: For information about begin using the camera with older types of connections (PC-Card, parallel interface, IRFlashLink etc), see the following documents on the CD:

- Installation Hints (Publ. No. T559004)
- System configurations (Publ. No. 1 557 783)
- Camera connections (Publ. No. T559010)

In order to be able to show a live image, ThermaCAM™ Researcher Professional has to establish a software connection to the camera. The status information of the **Camera Control** panel will reveal if the program is trying to connect to the camera or not. If it says **Disconnected**, you will have to order a new connection by selecting **Connect** from the **Camera** menu.

On the same menu, there is a **Normalized connection** command which sets the camera in a state suitable for almost any computer during the connection process.

6

If ThermaCAM™ Researcher Professional is showing a disk image, you will have to select **Show Camera Image** from the **Camera menu** or press CTRL + L or click this toolbar button to make the program consider connecting to the camera and displaying its image.

10418703;a2

Figure 6.2 **Show camera image** toolbar button

The purpose of doing these soft connections/disconnections is that it enables you to run two or more copies of ThermaCAM™ Researcher Professional. You can disconnect the camera from one copy and connect it to another instead.

If you have two (or more) FireWire cameras, you can connect each camera to a separate copy of ThermaCAM™ Researcher Professional, perhaps with a slight loss of performance.

After the connection is established, it may still take some time before the logo image disappears. The camera may have to run for a while, before its detector is cool enough to produce a live image.

SEE ALSO: If you get into connection difficulties here, see section:

- 6.2.4 – About connection difficulties on page 30

NOTE: Do not remove the FireWire cable or switch off the camera while ThermaCAM™ Researcher Professional is running unless you have selected **Disconnect** from the **Camera** menu first.

The **Camera Information** dialog box and the **Camera Control** panel are the two main ways by which you communicate with the camera.

Take a quick look at the **Camera Information** dialog box, which can be reached from the **Camera** menu or by clicking on the camera symbol to the right on the status line below the image. It will probably show the name of the camera and that it is working. Otherwise the reason of failure is displayed here (or in the **Device Status** panel displayed if you click on the interface symbol to the lower right of the program window).

Let's take a quick look at the **Camera Control** panel. We will study it in more detail in the next sub-chapters.

Let's examine the **Measurement Range** list on the second tab. Select a range, which covers the expected measurement temperatures. The range limits are blackbody temperatures, so if your measurement target has a shiny surface with a low emissivity, you will be able to make measurements above the range limits.

An image, which is probably blurry, is shown on the screen. Otherwise, click the candle toolbar button to get a better scale in the PC. Some cameras have their own ways of adjusting the image and improving its quality. See the appropriate camera control description below.

10418803;a2

Figure 6.3 **Candle** toolbar button

Aim the camera onto the target. Focus the camera, either by using the focus buttons on the **Camera Control** panel or the three buttons below (found on the standard toolbar). You also have the option to use the F9/F11/F12 keys.

10418903;a2

Figure 6.4 **Focus** toolbar buttons

Click the arrow target button to autofocus the camera.

Hold down the other buttons in order to run the focus motor of the camera towards infinity or towards the lens. Release the button when the focus is OK, or rather slightly before. There is a small delay before the focus motor stops.

If you are satisfied with your image, you can freeze it by clicking this button on the standard toolbar or pressing CTRL + F or F8:

10419003;a2

Figure 6.5 **Freeze** toolbar button

If it is an interesting image, you had better save it on disk right now. If you leave the program without first recording the image, the image is lost.

SEE ALSO: For more information, see section:

- 6.5 – How to record IR images on page 34

6.2.1 ThermoVision™ A-series Camera Control

ThermaCAM™ Researcher Professional allows you to connect A-series cameras either through a FireWire™ interface or through an Ethernet™ interface.

ThermoVision™ model	Interface to ThermaCAM™ Researcher Professional
A20 M/V Ethernet™	None
A40 M/V Ethernet™	None
A20 M FireWire™	FireWire™
A40 M FireWire™	FireWire™
A20 V FireWire™	None
A40 V FireWire™	None
A320	Standard Ethernet™
A320G	Gigabit Ethernet™

When more than one camera is detected, this dialog box is displayed.

10770203;a1

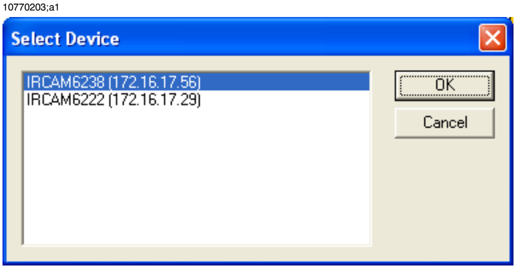

Figure 6.6 **Select device** dialog box

The Ethernet™ cameras will not be detected, unless they have been assigned an IP-number (like 172.16.17.56 above). This can be done automatically by a DHCP server or manually by a utility program which is distributed with the camera.

The control panel below is used for the ThermoVision™ A-series cameras.

10431203;a1

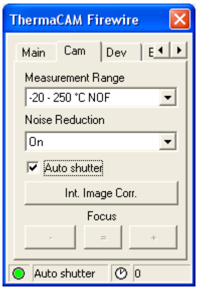

Figure 6.7 **ThermoVision™ A-series FireWire™** dialog box

If some button is disabled on your camera control, it is because your particular camera does not support that function.

The selected **Measurement Range** should cover the expected measurement temperatures. The range limits are blackbody temperatures, so if your measurement target has a shiny surface with a low emissivity, you will be able to make measurements above the range limits.

If you click the **Int. Image Correction** button on the **Camera Control** panel, the camera will respond by making a rather heavy clicking sound when the internal shutter is pulled and adjust its own temperature scale once to the current image. It is highly recommended to use the **Int. Image Correction** function now and then, since it improves the image quality. Select the **Auto shutter** option if you want an automatic internal image correction. This automated process can be disabled as it may affect the recording of images. When you switch it off, a warning will appear on the status field of the control. This warning will become red if you leave it switched off for a long time.

NOTE: There is a related function in the **Image** menu, on the standard toolbar and on the scaling toolbar. That function is called **Auto Adjust**. It will continuously adjust the scale to the image locally, within the PC.

If noise reduction is set to **On**, it will blur the image of moving objects.

If the camera is connected to the PC using the ThermaCAM™ Connect 2.0 software and ThermaCAM™ Researcher at the same time, the live image may seem frozen.

The **Downsample** checkbox is only available for A20 cameras. This option affects how much disk space each image will occupy when stored on the hard disk. If enabled, disk space for each image will be significantly reduced. However, a performance penalty (in terms of apparent image quality, but not in measurement) is introduced when storing and reading image files.

6

10430703;a2

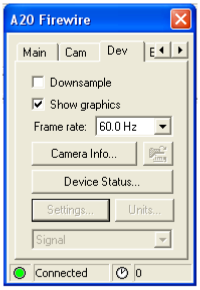

Figure 6.8 **ThermoVision™ A-series FireWire™** dialog box

Select the desired frame rate from the list box. The frame rate specifies how many images per second will be captured of the target in question.

NOTE: For cameras with a fixed frame rate, this selection will be unavailable.
NOTE: For some cameras, frame rates higher than 25/30 Hz may not be supported.
NOTE: For some computers, frame rates higher than 25/30 Hz may not work properly.

6.2.2 ThermaCAM™ S-series Camera Control

This control panel is used for ThermaCAM™ S60, ThermaCAM™ S40, ThermaCAM™ SC640, and similar camera models.

10419103;a1

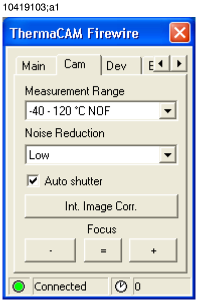

Figure 6.9 **ThermaCAM™ S-series FireWire™** dialog box

If some button is disabled on your camera control, it is because your particular camera does not support that function.

The selected **Measurement Range** should cover the expected measurement temperatures. The range limits are blackbody temperatures, so if your measurement target has a shiny surface with a low emissivity, you will be able to make measurements above the range limits.

If you click the **Int. Image Correction** button on the **Camera Control** panel, the camera will respond by making a rather heavy clicking sound when the internal shutter is pulled and adjust its own temperature scale once to the current image. It is highly

recommended to use the **Int. Image Correction** function now and then, since it improves the image quality. Select the **Auto shutter** option if you want an automatic internal image correction. This automated process can be disabled as it may affect the recording of images. When you switch it off, a warning will appear on the status field of the control. This warning will become red if you leave it switched off for a long time.

NOTE: There is a related function in the **Image** menu, on the standard toolbar and on the scaling toolbar. That function is called **Auto Adjust**. It will continuously adjust the scale to the image locally, within the PC.

At the bottom of the **Cam** tab, there are three focus buttons: Near focus (**–**), auto focus (=) and far focus (+).

If noise reduction is set to **Low** or **High**, it will blur the image of moving objects.

The camera control will block the camera power down function to ensure proper operation during image recording. To prevent the camera from shutting down when disconnected, make sure that the power down timeout is disabled in the camera.

6

10566703;a1

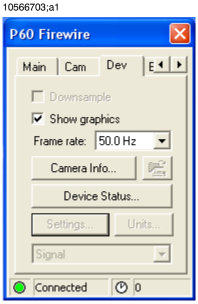

Figure 6.10 **ThermaCAM™ S-series FireWire™** dialog box

Select the desired frame rate from the list box. The frame rate specifies how many images per second will be captured of the target in question.

NOTE: For cameras with a fixed frame rate, this selection will be unavailable.
NOTE: For some cameras, frame rates higher than 25/30 Hz may not be supported.
NOTE: For some computers, frame rates higher than 7 Hz may not work properly.
NOTE: Use the **Normalized connection** command on the ThermaCAM™ Researcher Professional **Camera** menu if connection fails due to a too high frame rate.

6.2.3 SC4000/SC6000 Camera Control

This control panel is used for ThermoVision™ SC4000/SC6000 cameras. It has a **Cal** tab, a **NUC** tab, a **Dev** tab, and optionally a **HSDR** tab for calibration, non-uniformity correction, device handling, and high speed data recording.

10755103;a1

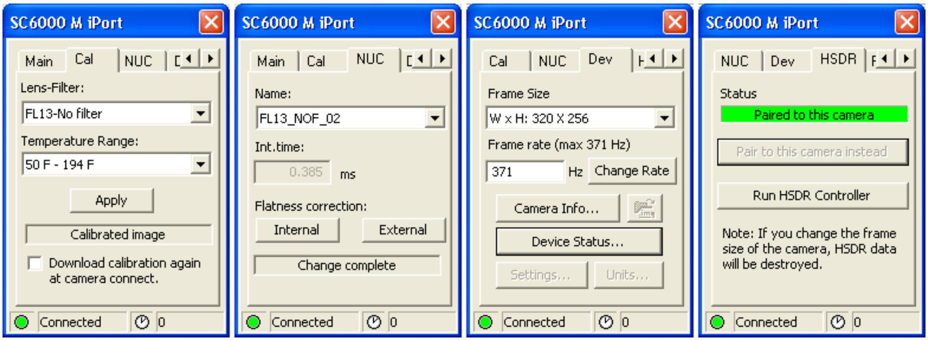

Figure 6.11 Cumulus iPort – camera control tabs

If a button is disabled on your camera control, it is because your particular camera does not support that function.

The **Lens-Filter** list contains the calibrated lenses and filters of your camera. The **Temperature Range** list shows the calibrated ranges for the chosen lens and filter in the first list. When you have selected your lens, filter and range, please press the **Apply** button.

The calibration file of the camera is normally downloaded to your PC when you connect to the camera for the first time. If you need to refresh this information, mark the **Download** check box, disconnect and connect again.

The **Name** list on the **NUC** tab shows the NUC tables currently stored in the camera. All tables are shown, not only those associated with a calibration. The tables contain non-uniformity correction data, integration time, frame size and other settings. If you select a NUC name from this list, you will switch to that table but get a non-calibrated IR-image. To get a calibrated image, you have to use the controls on the **Cal** tab.

The **Int.time** field shows the current integration time in milliseconds.

To improve the image quality, you can apply an **Internal** or **External Flatness correction**. By allowing the camera to look at an internal or external thermally flat surface, with a temperature well within the current temperature range limits, you can even out many image distortions. Just press the **Internal** or **External Flatness correction** buttons. You will not invalidate the current calibration if you do this, but the name of

the current NUC table is lost. The quality improvement can be considerable, especially if external correction is used and the camera recently was switched on. The external correction is better, because it also includes the lens non-uniformities.

The **Frame Size** list on the **Dev** tab shows a number of alternative image sizes for calibrated cameras. If you reduce the frame size you can increase frame rate without overloading the camera. Fill in a new value in the **Frame Rate** edit box and press **Change Rate** to do this. The current maximum recommended frame rate is shown above the button. Even if the camera doesn't get overloaded, your computer can still have difficulties with high frame rates.

If you should happen to increase the frame size without remembering to reduce the frame rate, ThermaCAM™ Researcher Professional will reduce it to 5 Hz for you.

If the camera somehow was set to conditions overloading the computer, use the **Normalised Connection** alternative on the **Camera** menu to reset them when you connect the camera.

The **Camera Info** button brings up a dialog window with information from the calibration of the camera.

The **Device Status** button shows information regarding the connection to the camera.

The **HSDR** tab will only show up if a ThermaCAM™ Researcher HSDR module is installed on the computer. The High Speed Data Recorder is a unit which captures a very high speed raw pixel data stream from the camera and stores it directly on disk. The recording can afterwards be converted into an image format suitable for ThermaCAM™ Researcher. The camera calibration will then be preserved.

You must pair the camera to the HSDR before you can begin using the HSDR Controller software to make HSDR recording.

It is not a very good idea to change the Frame Size setting in ThermaCAM™ Researcher Professional when you have precious data stored in the HSDR, since the change will wipe out all stored data. When a HSDR recording is in progress, the frame size list box will become disabled.

6.2.4 About connection difficulties

At times, you may run into difficulties establishing a connection with the camera. Here are some suggestions on what you can do:

Problem	Possible cause & solution
The program is having problems with the camera. It only works now and then.	Verify that the FireWire cable is properly connected to the computer and the camera. Always exit the program or select **Disconnect** from the camera menu before you disconnect or switch off the camera.
The program refuses to establish a contact with the camera. The status information keeps saying **Disconnected** while the camera is running.	The camera may be connected to another copy of ThermaCAM™ Researcher Professional. Switch over to that one and disconnect the connection. Now the new ThermaCAM™ Researcher Professional can connect to the camera.

6

SEE ALSO: For information about begin using the camera with older types of connections (PC-Card, parallel interface, IRFlashLink etc), see the following documents on the CD:

- Installation Hints (Publ. No. T559004)
- System configurations (Publ. No. 1 557 783)
- Camera connections (Publ. No. T559010)

6.3 How to display an IR image

6.3.1 Obtaining a good IR image

In order to get a good image from the camera, you should establish a connection, select an appropriate measurement range, auto adjust it, and focus it as described in the previous chapters.

No matter if you have a live image, a frozen image or a disk image, you should now consider the object parameters (emissivity, reflected temperature, atmospheric temperature, relative humidity of the air, the distance and the external optics transmission and temperature). They describe the physical properties of the body of interest and its environment and the atmosphere between the object and the camera. You can reach them via **Settings** in the **Image** menu or this button:

10419903;a1

Figure 6.12 **Image settings** toolbar button

SEE ALSO: For more information about object parameters, see sections:

- 13 – Thermographic measurement techniques on page 105
- 16 – Theory of thermography on page 121
- 17 – The measurement formula on page 131

10426803;a2

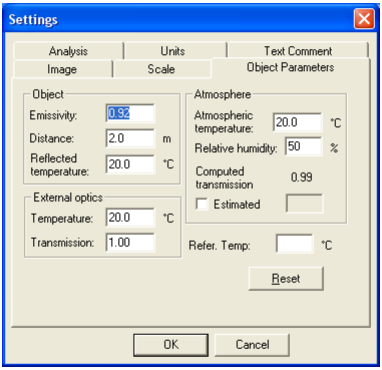

Figure 6.13 **Settings** dialog box

It is important that these parameter values become correct. Otherwise the scale temperatures and displayed colors will be wrong. The image parts for which the object parameters are wrong will get incorrect temperatures and colors. The measurement functions have object parameters of their own which are used to handle the case when there are two different targets in the same image.

SEE ALSO: To calculate the emissivity of an object, see section:

- 6.8.9 – Emissivity calculation on page 59

If the colors of the image are inappropriate, you can change them. The selection **Palette** toolbar button will bring up a dialog box with the palettes available.

10420103;a1

Figure 6.14 **Palette** toolbar button

Contrary to what you might think, the **Show saturation colors** option enables specific coloring of image points, which are outside the current temperature scale. The **Show out of range colors** option enables specific coloring of image points, which are outside the detectable range of the camera.

You can change the temperature scale with this control bar:

10420203;a2

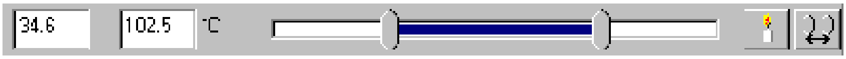

Figure 6.15 Control bar

You can use the slider to search for a good scale or to set fixed limits. Remember that the maximum temperature always has to exceed the minimum temperature. Click on the input fields if you want to edit them and hit the ENTER key afterwards. If you select **Auto Adjust**, you will find that an attempt to find the optimum scale is made for each new image. A small part of the temperature span of the image is however wasted, to minimise the effect of noise in the image. The measurement areas have a related auto adjustment function, which adjust the scale based on the area.

The rightmost button will keep the distance between the slider controls fixed.

Sometimes, when a live camera image is shown, you can find it impossible to change the scale in ThermaCAM™ Researcher Professional. This is when the camera has been set to continuously adjust the level or span of the image. Switch that camera setting off.

Finally, in the **Image** tab of the **Settings** dialog box, there are a few more options you can explore:

10426903;a2

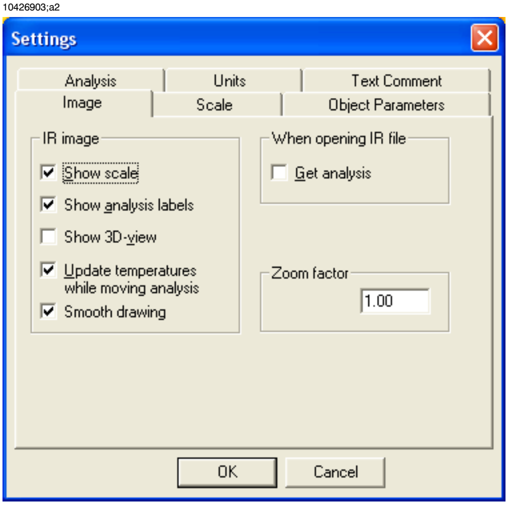

Figure 6.16 **Image** tab of the **Settings** dialog box

The **Show scale** option switches the display of the temperature and color scale on/off.

The **Show analysis labels** option will switch the display of the label texts on/off.

The **Show 3D-view** option will display a pseudo-3D version of the image.

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The **Update temperatures** option has to do with the update of OLE links, profile, histogram and result table when analysis tools are moved around in the image.

The **Smooth drawing** option makes the image appear to be less noisy, without affecting the measurement results. Isotherms can look less crisp.

The **Get analysis** option should not be used unless your images contain analysis tools that vary from image to image, which normally isn't the case.

The **Zoom factor** makes it possible to temporarily enlarge the centre of an image.

6.3.2 Transferring an IR image with OLE

If you want to display your image in a program not designed for IR images, you have to use OLE to make it visible. Use the **Copy session and image** toolbar button or the same command of the **Edit** menu.

10420503;a1

Figure 6.17 Copy session and image toolbar button

6.4 How to trigger ThermaCAM™ Researcher Professional from outside

If your target is active only on certain occasions, you might well want to tell the program when it should examine at the target. Two functions in ThermaCAM™ Researcher Professional work under such conditions. The recording functions that collect images, and the plotting functions that collect measurement results.

They can conditionally record or plot not only at certain times, but also on external trig pulses. The parallel interface has a trig input connector, which is the default trig source. In addition, a free COM port or a LPT port can be used as the external trig source.

The external trig increments a trig counter which is stored with each image. The value of this counter can be displayed in the **Play Images** toolbar bar and the result table. For COM or LPT trigs, the counter only counts one trig pulse per image.

The source for the external trig is selected from the **Recording Conditions** dialog box in the camera control panels.

6.4.1 External trig using the parallel interface or IRFlashLink

SEE ALSO: For more information, see the following documents on the CD:

- Camera connections (Publ. No. T559010)

6.4.2 External trig using FireWire/Ethernet

In ThermoVision™ A20, A40, and A320 cameras, you can mark image frames at the instant an alarm was triggered. By doing so certain trigger information is assigned to the image and the frame can be then identified in the image stream by ThermaCAM™ Researcher Professional. You can, for example, use this trigger information to make ThermaCAM™ Researcher Professional start or stop a recording.

6.4.3 External trig using the serial port

This trig source option uses the CTS input line on a free COM port. The COM port has an RS232 electrical interface.

Trig input using COM port	
DSUB-25 Pin 5: Trig Input.	Transition Low (<-3 V) to High (>+3 V) =trig. Close pin 4 and 5 to trig.
DSUB-9 Pin 8: Trig Input.	Transition Low (<-3 V) to High (>+3 V) =trig. Close pin 7 and 8 to trig.

SEE ALSO: For a more detailed description of the electrical interface, read the RS-232 specification.

6.4.4 External trig using the printer port

The printer port (LPT) option is only available on Windows 95/98/ME platforms. This trig source option uses a control signal on a free LPT port. The LPT port has a TTL electrical interface.

Trig input using LPT1 (or LPT2) DSUB 25 pin printer port.	
Pin 10: Trig Input.	Open circuit = high. (+2.4 V to + 5 V) Transition High -> low =trig.
Pin 22: Ground	Closing 10 - 22 = trig.

The LPT1 port is normally associated with the physical hexadecimal address 378 and the LPT2 port is associated with address 278. The camera control assumes that this is the case. Check your parallel port configuration in the **Control Panel** → **System** icon, to find out the physical address associated with the parallel port.

6.5 How to record IR images

You can only record images that come from the camera interface. The currently active measurement tools are not recorded with the images, but the current scale and object parameters are.

You have to click the camera button in order to get live images (or select **Show Camera Image** from the **Camera** menu or press CTRL + L on the keyboard).

10420603;a2

Figure 6.18 **Camera** toolbar button

6.5.1 Recording toolbar

When the camera becomes the image source, the following toolbar is displayed.

10420703;a2

Figure 6.19 **Recording** toolbar

It is primarily associated with recording sequences of image files, but can also be used to record single image files. The leftmost field shows the name of the file that will be stored next. The name consists of a base part (NEW) to which a sequence number is added (0002) and extension is appended (.IMG or .SEQ). The base part is a text string, which you can change in the **Recording Conditions** dialog box hidden under the stopwatch button on the same toolbar. The sequence number is controlled by ThermaCAM™ Researcher Professional and is increased by 1 for every image file or image sequence file.

A field showing the current condition for starting the recording follows the toolbar button with the start pistol.

A field showing the current condition for recording an image follows the toolbar button with the disk. No matter what the field says, the diskette button will always record one image, even if the start condition is not fulfilled.

The next button will temporarily stop the recording: **Pause.**

A field showing the current condition for stopping the recording follows the toolbar button with the chequered flag. No matter what the field says, the flag button will always stop the recording.

The second last button will bring up the **Recording Conditions** dialog box.

The very last button will start the replay of the recorded images in another copy of ThermaCAM™ Researcher Professional.

To start the replay of the recorded images in the current copy of ThermaCAM™ Researcher Professional, just click this button in the standard toolbar:

10420803;a2

Figure 6.20 Button used to start replay of recorded images

6.5.2 Recording Conditions dialog box

You can reach this dialog box from the **Recording** toolbar and the **Conditions** item of the **Recording** menu and the **Recording** tab of the camera control.

10420903;a2

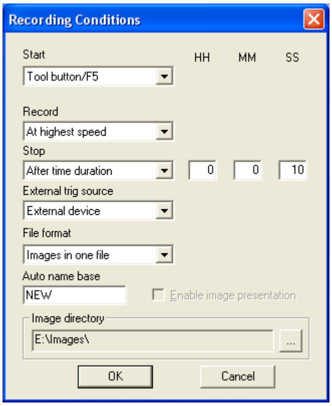


Figure 6.21 Recording conditions dialog box

Recordings are controlled by three conditions: Start, Record and Stop. In this dialog box you can set these conditions as well as the base part (auto name base) of the file names and the directory where the recording shall be made. If you select the images in one file option, images will be recorded to a single file, which will reduce the number of files to handle and increase the recording speed. The dotted button beside the current directory field leads to a directory browser.

Sequence recordings can start at:

- Tool button/F5
- At absolute time
- External trig (plus a specified delay: for instance **00 00 05**)

Images can be stored either:

- At highest possible speed. This means that no images will be displayed during the recording, unless you select the **Enable Image Presentation** option. That will however reduce the recording speed.
- At HH MM SS interval. *Example:* **00 05 30**
- At key trig F5. This choice will disable the start or stop conditions
- At image interval. *Example:* Using 2 will skip two images between recordings.
- At external trig

The recordings will stop when the stop condition is reached. The following possibilities exist:

- Tool button/F5. The flag button is always active during a recording.
- After XX stored image(s). Fill in the number desired like this: **88**
- After time interval HH MM SS.
- At external trig (plus a specified delay: for example **00 00 05**)

SEE ALSO: For more information about how to connect an external trig, see section:

- 6.4 – How to trigger ThermaCAM™ Researcher Professional from outside on page 33

You might find it a bit difficult to get your recording conditions right for SC3000 cameras. At the higher speeds than 50/60 Hz, the camera puts several images into every normal speed image sent to the frame grabber. The frame grabber will still grab its images in the normal way, throwing away the extra information sent by the camera. You will only get hold of the high-speed images when using **At highest speed** recording and the **Images in one file** option.

If your recording will last for a very long time, it might be a good idea to control it by OLE automation instead.

6.5.3 Full burst recording of images

SEE ALSO: For information about disk management, see section:

- 11 – Disk management on page 97

Only when you are using full burst recording, can you grab, store and study every image captured by the camera (except for the old Thermovision 1000).

If you have the parallel interface configuration or FireWire configuration or Gigabit Ethernet configuration and suitable disks and software, you should be able to get a full burst recording rate if you:

- Select the **Images in one file** option in the **Recording Conditions** dialog box.
- Do not run any program that consumes processor power at the same time, for example "fast find".
- Do not run any program that consumes lots of memory (such as the Microsoft® Office programs) at the same time.
- Do not let the local area network connection interfere. (Pull the plug!)
- Do not let the screen saver / lock screen software interfere.

In short, don't let the computer do anything else at the same time. When you use an external trig to control the burst recordings, these restrictions have to be observed even before the actual start. ThermaCAM™ Researcher Professional will capture all images in advance in order to be able to store the trigged image(s).

6.5.4 HSDR recording of images

For ThermoVision™ SC4000/SC6000 cameras a high speed data recording unit can be installed. It is enabled by the SC4000/SC6000 camera control.

SEE ALSO: For more information about the SC4000/SC6000 camera control, see section:

- 6.2.3 – SC4000/SC6000 Camera Control on page 28

6.5.5 OLE Automation recording of images

If you intend to record images at a slow or irregular rate, or wish to switch off/switch on a Stirling cooler or to perform an internal correction of the camera before each "shot", then OLE automation controlled recording will be your natural choice.

You need to have another program available with a Visual Basic for Applications (VBA) macro language capability that can give orders to ThermaCAM™ Researcher Professional. Here is an example for Microsoft® Excel, in which 20 images are recorded to disk using a 15-second time interval:

```
Sub SaveIR()
  Dim sess As Object
  Dim counter As Integer
  Set sess =
   GetObject("C:\Program Files\Research\Ole.irs")
  Counter = 0
  Do While counter < 20
    counter = counter + 1
    sess.RecordOneImage
    Application.Wait Now + TimeValue("00:00:15")
  Loop
End Sub
```

6.5.6 Recording with text comments

10431303;a1

Figure 6.22 **Recording conditions** dialog box

You can add text comments to the images you are recording, or change or delete existing ones. These text comments are applied to all future recorded images.

- To add a text comment, click **Add** and type the label and parameter value of the new text comment
- To change a value of a text comment, double-clicking the value and type a new text string
- To delete a text comment, select the text comment you want to delete and then click **Delete**

- To move a text comment up or down, select the text comment and then click **Up** or **Down**

If your recording is stored in one single file, you can not change the number of text comments during the recording – only their contents.

6.6 How to play back images

ThermaCAM™ Researcher Professional supports the following image formats:

- ThermoVision™ 400/800 + 900/1000
- AGEMA 550/570 + ThermoVision™ Alert + ThermoVision™ Sentry
- Prism DS
- Inframetrics 700
- ThermaCAM™ PM 100, 200, 300, 150, 250, 350, 180, 280, 380
- ThermaCAM™ PM 525, 545, 575, 595
- ThermaCAM™ SC 1000, 2000
- ThermaCAM™ PM 195, 295, 395 (UltraCAM)
- ThermaSNAP
- ThermaCAM™ SC 3000
- Indigo Merlin (*.img and *.tgw)
- Indigo Omega (*.img and *.tgw)
- Indigo Phoenix (*.img)
- Thermoteknix *.tgw, *.tmw, *.tlw
- ThermoVision™ 400/800 Tdiff-images
- ThermoVision™ 900/1000 Tdiff-images
- ThermaCAM™ Researcher Professional Tdiff-images
- Single Ttx-tgw images from Dynamite
- Difference images in Temperature
- Difference images in Object signal
- FFF and FFF-jpg-images
- FPF-format (save only)
- FFF and JPG with Dual ISO and Diff
- Ttx-tgw images with AVG
- SEQ-files with text comments

Such images are received by ThermaCAM™ Researcher Professional on disk.

When ThermaCAM™ Researcher Professional is showing disk images, the **Play recording** toolbar button on the standard toolbar is depressed:

10421003;a2

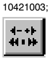


Figure 6.23 **Play recording** toolbar button

There are several ways in which a playback of images can be initiated. You can click **Play recording** or, on the recording toolbar, click the button **Play in a new window**:

10421103;a2

Figure 6.24 **Play in a new window** toolbar button

From the file menu, you can select **Open Session**, and read a session file from disk containing information from older, already stored sessions containing recordings. You can also copy and paste a recording session from one ThermaCAM™ Researcher Professional window to another. Furthermore, you can drag and drop image files or a session file from the Windows Explorer onto a ThermaCAM™ Researcher Professional window. Finally, you can use the **Open Images** function to put together a new selection of images (or change an existing one).

6.6.1 Open images dialog box

You start the dialog box with this toolbar button (or by pressing CTRL + I keys or by the **File** and **Image** menus).

10421203;a2

Figure 6.25 **Open images** toolbar button

It will bring up the following dialog box:

10427003;a1

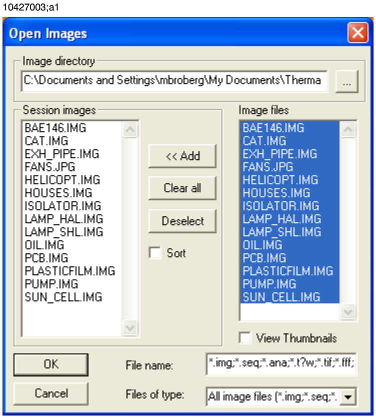


Figure 6.26 **Open images** dialog box

The top field of this dialog box permits you to edit the name of the directory where the images are stored. Click **OK** or the ENTER key once after editing this text in order to refresh the dialog box. The dotted button leads to a directory browser.

The left half of the dialog box shows the list of images currently in use by this session.

The right half of the dialog box shows a list of image file names in the image directory. All the files in this list are highlighted by default.

There is a file name filter field by which you can affect the directory listing. You could for instance change *.img to t*.img to list files beginning with the letter t. Click **OK** or the ENTER key once to refresh the list afterwards.

If you select the **View Thumbnails** option, the layout of the right half of the dialog box will change drastically:

10427103;a2

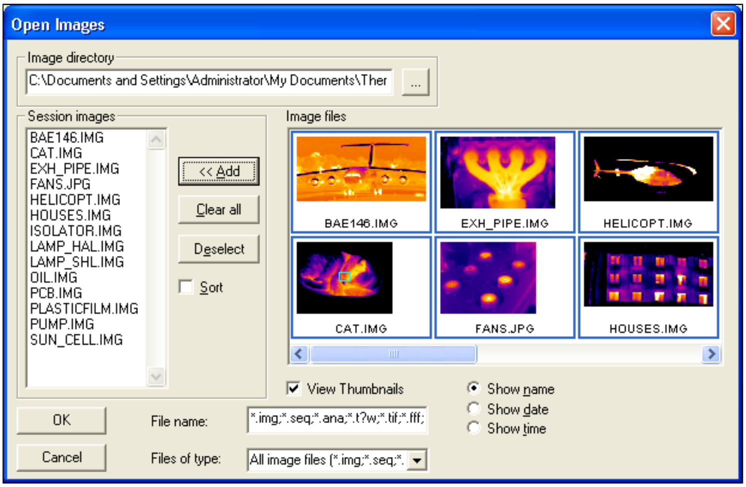


Figure 6.27 **Open images** dialog box – **View thumbnails** option selected

The list of files will become a list of images instead. The images with a blue frame are the highlighted ones. The images are always displayed with the iron palette and with their own scale, object parameter, analysis and zoom settings.

Using the three radio buttons below the images, you have the option of displaying the date or time instead of the image names.

The buttons in the middle of the dialog box manipulate the names of the list to the left. The << **Add** button will copy all highlighted file names from the right list to the left one. The **Clear All** button will clear the left list. The **Deselect** button will remove highlighted items in the left list. If no items are highlighted, nothing is removed. The image files are not deleted from disk by this operation, only their names in the list.

The **Sort** selection will rearrange the names in the left list. They become sorted in alphabetical order and duplicate names are removed.

This gives you the possibility to arrange the list of names, as you like.

You should use mouse clicks in combination with holding down the SHIFT or CTRL keys in order to manipulate the highlighting of the lists.

You may add both single images and image sequence files to the left list at the same time, although it is probably not very common practice.

When clicking **OK**, you select all the image files in the list to the left for playback by ThermaCAM™ Researcher Professional. This action activates the **Play images** toolbar.

6.6.2 Play images toolbar

When disk images are being replayed, this toolbar is displayed:

10421503;a2

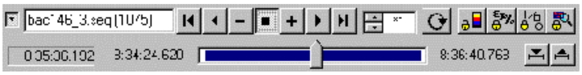


Figure 6.28 **Play images** toolbar

It resembles the controls found on ordinary video tape recorders quite a lot. You can step forward and backward one image at a time. You can play your images in any direction fast or slowly or jump to the end/beginning of the images.

You set the replay rate in the list box.

- ***1** means full speed from disk
- ***2** means twice full disk speed (i.e. every other image is not shown)
- **÷2** means half full speed

You can double-click on the control to make it return to ***1** speed.

10421603;a2

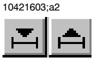


Figure 6.29 Selection buttons for parts of images

These two buttons let you select one part of the current images. Click the left one when you are looking at the first (leftmost) image to be selected. Click the right one when you look at the last (rightmost) image to be selected. A blue indicator will mark your selection in the control.

When you have marked a selection, the "to end/to beginning" buttons will instead jump to the next mark and the autorewind button will change its behaviour. Printouts can be made based to the selection and, in the case of a sequence file being displayed, editing of this file can take place.

You can remove the selection by choosing **Clear Markers** in the **Recording** menu

10421703;a2

Figure 6.30 **Autorewind** toolbar button

This button enables autorewind mode. If a selection is made, it will be repeated continuously when replayed. If no selection is made, or autorewind mode is set to **All images**, the whole sequence is repeated.

The text field to the left shows the name of the current image in the sequence. This field can be edited if you click in it. You may write:

- A file name, including the extension, present in the list
- The number of a particular image. 1 signifies the first image
- A relative number. **+5** means five images ahead. **-12** means twelve images back

Hit ENTER on the keyboard to finish the editing.

SEE ALSO: For information about associated shortcut keys, see section:

- 5.7 – Shortcut keys on page 19

10421803;a2

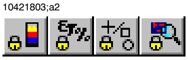


Figure 6.31 Control buttons used when switching images

These four buttons control how the program behaves when you switch from one image to another.

SEE ALSO: For more information about these buttons, see section:

- 6.9.1 – Making measurements in playback on page 68

6.6.3 Replay Settings dialog box

If you choose **Replay Settings** from the **Recording** menu the following dialog box will appear.

10421903;a1

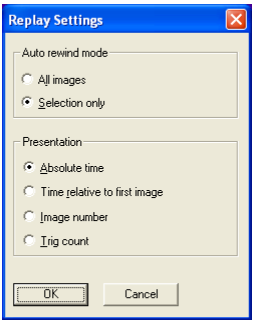


Figure 6.32 **Replay settings** dialog box

Auto rewind mode: In rewind mode you can chose between repeating the whole sequence or just the marked part.

Presentation: What is presented on the play images toolbar.

Absolute time shows the actual recording time.

Time relative to first image shows the time difference of the current image compared to the first image. If the current image is recorded earlier than the first image, ######## is shown instead.

Image number shows the image ordinal number.

Trig count shows the external trig count stored in the image.

6.7 How to edit/convert sequences

It will happen now and then that you record too many images and would like to extract the essential part of a sequence and/or convert it to some other image format, such as AVI or BMP.

To edit a sequence of images, open it with the **Open Images** dialog box and use the **Selection Start/Selection End** buttons on the **Play Images** toolbar to mark some images. Step to the first image you intend to edit and click the left one of the buttons, then step to the last image to edit and click the right one. A blue ribbon will be shown in the image slider control.

10422003;a1

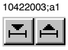


Figure 6.33 Selection buttons for parts of images

6.7.1 Removing/Copying all selected images

Having selected some images, you can choose **Remove Selection** from the **Recording** menu. Then you will be asked to confirm it is the right selection.

You cannot undelete images that become removed. Depending on the sequence size this operation may take several minutes. The frame numbers of the images following the removed part will be resequenced.

Removing images only works if all the images are in the same sequence file (.seq)

Instead, if you choose **Copy Selection** from the **Recording** menu, and then choose output format **Seq**, you may select a directory and enter a file name for the new sequence file. Depending on the size of the selection this operation may also take several minutes.

Copying images in this way only works if all the images are in the same sequence file (.seq)

6.7.2 Removing/Copying some selected images

Having selected some images, you can also choose **Reduce Selection** from the **Recording** menu. This dialog box will appear:

10422103;a1

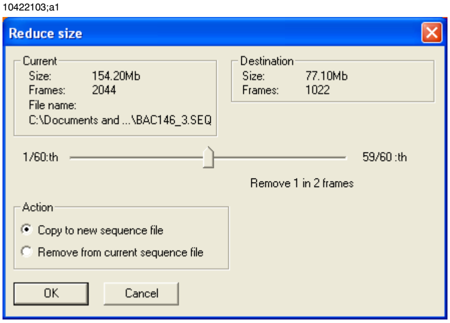


Figure 6.34 **Reduce size** dialog box

If you move the slider in the centre of the dialog box to the right, more of the sequence file is kept. If you move it to the left, less is kept.

Select whether or not you wish to copy the sequence to a new file, and click OK.

You cannot undelete images that become removed. Depending on the sequence size this operation may take several minutes. The frame numbers of the images following the removed part will be resequenced.

The reduction works only if all the images are in the same sequence file (.seq)

6.7.3 AVI/BMP/MatLab/FPF/SAF files from selected images

Having selected some images, you can convert them to other image formats by choosing **Copy Selection** from the **Recording** menu. This dialog box will appear:

10427203;a1

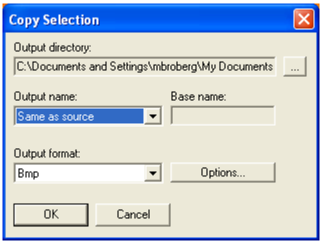


Figure 6.35 **Copy selection** dialog box

Set the output directory, output name and options of preferred output format and click OK to start the copy. Depending on the size of the selection this operation may also take several minutes.

SEE ALSO: For more information about output formats, see section:

- 6.8.16 – Studying whole images on page 63

SAF (Standard Archive Format) files can only be created if all the selected images belong to the same sequence. The created images will get the following file name extensions:

- *.stmov, *.inc, and *.pod, respectively, if a sequence or part of a sequence is saved
- *.sfimg if one image in a sequence is saved

If you click the options button when the output format is AVI, you will be able to set the AVI codec to **other**. This, in turn, causes the **Copy Selection** dialog box to show the following dialog box when you click its **OK** button.

10427303;a1

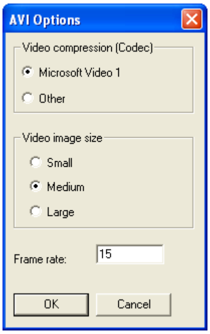


Figure 6.36 **AVI options** dialog box

Here you can choose among the compressors installed in your computer and configure them. Note that some of them might only be able to decompress AVI files, not to compress the files.

You should always check that the receiver of the AVI file is able to decompress it.

NOTE: AVI creation using 256 colors may cause problems. If you experience difficulties, please use a higher number of colors.

6.7.4 Subtracting selected images

Regarding image subtraction as an image conversion function might seem strange, but that is really what this type of work is all about. You select some images out of a sequence, order them to be subtracted and get another sequence containing difference images as the result.

Why subtraction? Well, the most important usage of this function is for making comparisons. You can compare images of the same (or similar) object(s), taken at different times, in order to detect changes in temperature, position or shape.

Subtraction uses a reference image, taken when conditions are known to be good, in some sense, and subtracts the selected images with that reference. The subtraction is made in the current measurement unit, not in camera signal.

The reference image does not have to be located in the same directory as the selected images. The output images are put in the same directory as the selected ones, however.

To make a subtraction, select **Subtract Sel Images** from the **Recording** menu.

10422403;a1

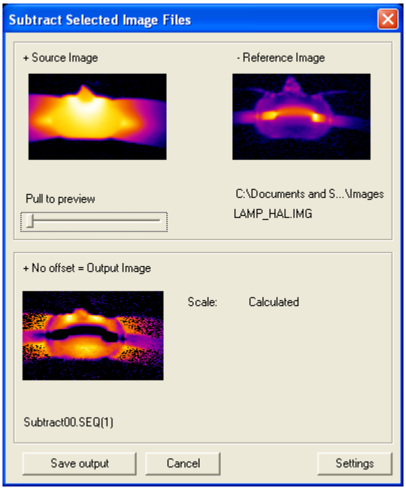


Figure 6.37 **Subtract selected image files** dialog box

On the dialog box shown, you can see most of the settings of the subtraction function, and also preview the subtraction by (slowly) pulling the slider. No images will be saved on disk until you click the **Save output** button.

The source images shown in the upper left corner are the ones you selected before starting the subtraction. The reference image is displayed in the upper right corner and the resulting image in the bottom left.

Click **Settings** to view the **Settings** dialog box.

10422503;a1

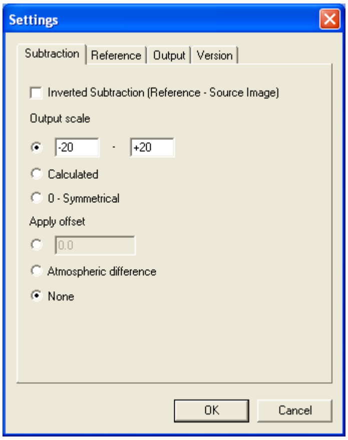


Figure 6.38 **Subtraction** tab of **Settings** dialog box

The first tab contains settings for the actual subtraction algorithm. You can invert the result, force a particular output scale and apply an offset (in case your images were taken under very different atmospheric conditions).

10422603;a1

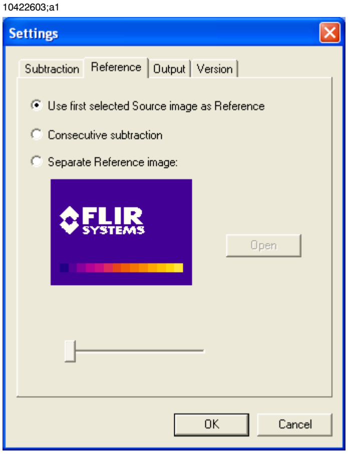


Figure 6.39 **Reference** tab of **Settings** dialog box

The second tab contains settings for the reference image. You can either use the first selected source image as your reference or perform consecutive subtractions or use a separate reference image.

In the last case, use the **Open** button to open your image and the slider to find it, if it is inside a sequence.

10422703;a1

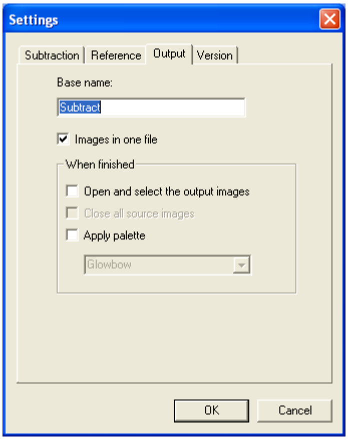


Figure 6.40 **Output** tab of **Settings** dialog box

In the output tab you can set the name base for the output images. A number will be appended to the base, to make the name unique.

When the subtraction is finished, you can, at will, open and select the output images, close all previous source images and a new palette to the images.

There are two special purpose subtraction palettes – **Midgrey** and **Midgreen**. Since the 0-level of a difference image normally is in the middle of the scale, there has to be a neutral color for that value.

Click **OK** to return to the **Subtraction** dialog box. Now, click **Save Output** to get the subtraction going.

While the images are being subtracted, a progress bar is being displayed.

When the subtraction is over, and the output images are displayed, you may notice that the measurement units have changed. From °C to dC, for instance. This is because there is no longer any absolute temperatures in the real sense. Just differences indicating how much the temperature of the object has changed.

You may also notice that most of the object parameters have lost their meaning. Only the object distance is valid for difference images.

You may also notice that there was overflow in the subtraction. Subtraction has a limit, which normally is ±400 dC. You can use the offset to get around that limit, if it is disturbing.

Subtraction is an operation that can’t be undone. This means that if you find out that something (an object parameter perhaps) of the source or reference image was wrong, then you have to change it and run the subtraction once again to get accurate results.

6.8 How to make single image measurements

Sometimes you just need to look at an IR image to measure it. You can look for anomalies, hot or cold areas and get an impression of their temperatures just by comparing the colors with those of the temperature scale. By choosing a suitable scale and palette, such things can be made to appear quite clearly. This chapter will, however, be devoted to something else: how to use the analysis tools to get numerical temperatures and statistical information out of a single image.

The analysis tools will show their results in the result table, plot, profile or histogram window or directly inside the IR image. Results are also available through the OLE functions, such as **Copy Value**.

Both absolute measurements (i.e. the result is a real temperature) and relative measurements (i.e. the result is a difference temperature) can be made. The relative measurements are made relative to the reference temperature that you can enter in the dialog box **Image Settings** (in the **Image** menu), the **Object Parameters** tab. Relative measurements are only available for some camera types

The analysis tools work both with live images and recorded images.

The analysis tools are applied by activation of one toolbar button at a time. These are in this toolbar:

10422803;a2

Figure 6.41 Analysis toolbar buttons

When you click on one of these buttons (except the formula button), it will stay depressed until you have dragged the analysis tool inside the IR image or the color scale. If you change your mind, click on the button again, and it will pop up.

If you hold the CRTL button of the keyboard down while placing the tool on the image, the button will stay down and you will be able to continue adding another tool of the same kind. The removal button works in the same way.

Once the symbols have been drawn, you get the opportunity to bring up a menu for each symbol by "hovering" with the mouse cursor above the symbol and clicking with the right mouse button. The symbol will respond by changing its color (and the mouse cursor) when you can catch it.

Formula results are not presented in the IR Image, instead they are available in the result table, plot and through OLE functions.

Three of the toolbar buttons are equipped with menus that you can activate by moving the mouse a little before releasing the mouse button. This is indicated with a small arrow facing downward on those buttons.

6.8.1 Isotherm tool

An isotherm is a marker in an infrared image that highlights areas where the radiation from the object is equal. The name isotherm can be misleading, since it implies that equal temperatures are highlighted. This is only true if the emissivity of the object is the same all over the image.

If you bring up the menu on this button, you will see that there are five types of isotherms in ThermaCAM™ Researcher Professional. The most commonly used one is the **Interval** isotherm. It will highlight a temperature interval with a certain (selectable) width. There is a marker in the color scale to indicate the position of the isotherm. The temperature measurement value associated with the interval isotherm is taken at the top of the isotherm, regardless of how wide it is.

The **Above** isotherm will highlight all temperatures above a temperature value and the below isotherm the opposite.

Dual above and **Dual below** isotherms are an above/below isotherm attached to an interval isotherm with a different color. The dual isotherms highlight two temperature spans.

You activate the tool and set its level by clicking on the color scale beside the image. If the scale has been switched off in the **Image Settings** dialog box, you have to switch it on again.

Isotherms can be viewed in a transparent mode. Select the **Analysis** tab from the **IR objects settings** dialog box and select the transparent isotherm check box.

Transparent isotherm is best viewed with a grey palette, because the isotherm will always be presented in the image with red for above, green for interval and blue for below. If two isotherms of the same kind are present, the latest added isotherm will be shown in yellow.

It is possible to change the isotherm level after it has been created. You “catch” the level in the color scale by pressing the left mouse button precisely on the level and pull it to where you want it to be. Then release the left mouse button. The interval isotherm can be changed in three ways. You can catch it in the upper and lower ends, changing them. You can also catch it in the middle and move both ends at the same time.

Isotherm limits cannot exist outside the maximum or minimum temperatures of the scale. Hence they will follow the scale limits, if the span of the scale is reduced.

You can use two isotherms with different colors at the same time.

The temperature values of the isotherm are shown in the result table window or through OLE. You can obtain the following values: Temperature, width (interval isotherm only) and temperature relative to the reference temperature.

The temperature value given for the interval isotherm, is that of the upper limit.

The isotherm always uses the object parameters of the IR image.

6.8.2 Spot meter tool

This tool measures the temperature in one spot on the image and shows the result in the result table or beside its symbol in the IR image. The results are also available through OLE. You can obtain the following values: Temperature, temperature relative to the reference temperature, emissivity, object distance and the image co-ordinates of the spot meter.

Spot meters are called **SP01**, **SP02**... **SP99**.

You create a spot meter by first clicking on the spot meter toolbar button and then on the desired position in the image.

You move a spot meter by “catching” it with the mouse. You click the left mouse button on top of the cross hair and drag it into the place you want. The spot meter will then jump to that position.

6.8.3 Flying spot meter

This tool only measures the temperature at the mouse cursor and displays it beside the cursor in a tool tip window.

There is just one single flying spotmeter.

You can click with the left mouse button on the image to create fix spotmeters in that position, if you like.

6.8.4 Area tool

This tool measures the maximum, minimum, average and standard deviation temperature within a chosen part of the image and presents these values in the result table window or beside its symbol in the image. Results can also be displayed graphically in the histogram window. The results are also available through OLE.

You can obtain the following values: Minimum, maximum, average and standard deviation temperature, the same relative to the reference temperature (except for the deviation), emissivity, object distance and the image co-ordinates of the area.

Areas are called **AR01**, **AR02**... **AR99**.

You create a box area by first clicking down the box button and then moving the mouse to one of the corners of the new box. Hold the left mouse button down and drag the mouse to the opposite corner and release the button.

You create a circle area by first clicking on the circle button and then moving mouse to the centre of the new circle. Hold the left mouse button down and drag the mouse to some place on the circle border and release the button.

You create a polygon area by first clicking on the polygon button and then moving mouse to the first corner of the new polygon area. Click the left mouse button for each new corner and double click or hit the ESC key to finish adding corners.

You move an area by “catching” it with the mouse. You hold the left mouse button down inside the area and drag the whole area into the new position and release the button. If you hold down the CTRL key while moving the area, you create a copy of the area instead of moving it.

You reshape an area by catching the border or corner to be changed and dragging it along. Catching and dragging a polygon area border results in adding a new corner. You can remove a specific corner from a polygon area by using the analysis removal tool.

Areas can also be used to make local auto adjustments. That means adjusting the scale of the whole image to the temperature span within that particular area. It is very useful, if you want to make detailed studies of some part of the image. This function is only available on the right mouse button menu of the areas.

6.8.5 Line tool

This tool measures the minimum, maximum, average and standard deviation temperature along a straight or bendable line within the image. The temperature in one spot, the line cursor, can also be measured. These values are presented in the result table or beside the line symbol in the image. The line temperatures can also be graphically presented in the profile window. The results are also available through OLE. You can obtain the following values: Cursor, minimum, maximum, average and standard deviation temperature, the same relative to the reference temperature (except for the deviation), emissivity, object distance and the image co-ordinates of the line and a string with all the temperatures of the line.

Lines are called **LI01**, **LI02**... **LI99**.

You create a straight line by first clicking on the line button and then move the mouse to one of the ends of the new line. Hold the left mouse button down and drag the mouse to the other end and release it.

You create a bendable line by first clicking on the line button, and then drag the mouse just a little. A menu will now appear. Select the **Bendable line** item and start clicking on the image wherever you want the corners to be placed. Double-click with the mouse or press the ESC key to finish the creation.

You create a line cursor by first pressing the left mouse button on the line toolbar button while dragging the mouse to bring up the menu. Select the cursor item and move the mouse to the place on the line where you want to have the marker and click. You can see the temperature of the marker now in the profile window.

You move a line by "catching" the corners with the mouse. You hold the left mouse button down on the corner and drag it away. You can move the whole line by catching it in the middle.

You move its cursor by "catching" it and dragging it along the line. If you hold down the CTRL key while moving the line, you create a copy of the line instead of moving it.

6.8.6 Formula tool

This tool is used for adding and editing formulas.

A formula can contain all common mathematical operators and functions, such as +, -, *, / square root, etc. Also, numeric constants such as 3.14 can be used. Most importantly, references to measurement results, formulas and other numerical data can be inserted into formulas.

The formula button has a menu. If you bring up the menu you will find some frequently used formulas to add, in addition to entries leading to an add formula dialog box and an edit formulas dialog box.

The result of the formulas appears in the result table. You can also plot the result.

Click the **Formulas** toolbar button. The **Edit formulas** dialog box will appear:

10427403;a1

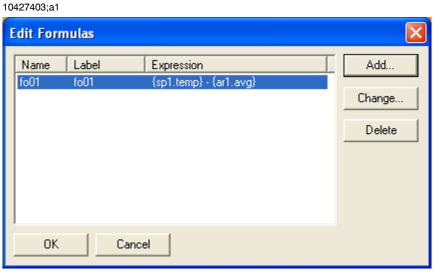


Figure 6.42 **Edit formulas** dialog box

Click **Add**, and another dialog box will be displayed, in which you define your new formula.

10427503;a1

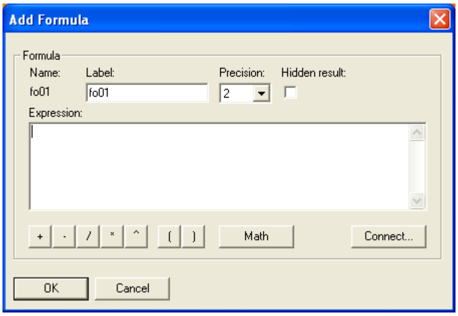


Figure 6.43 **Add formula** dialog box

The formula name is generated automatically and identifies the formula uniquely.

In the **Label** field, type a text describing your formula. This label will appear in the result table window.

Now, enter the expression of the formula. You may either type in the expression using the keyboard, or use the buttons in the dialog box. When you click on any of the buttons, the corresponding operator will be inserted into the expression. Following are the operators that can be used.

Operator button	**Operator**
+	Plus operator
-	Minus operator
/	Division operator
*	Multiplication operator
^	Power operator
( )	Parentheses, used for grouping

If you want to use other mathematical operators, such as sinus, select the appropriate function by clicking the **Math** button. Following are the functions that can be used.

Function name	**Function**
Acos	Arccosine
Asin	Arcsine
Atan	Arctangent

Function name	Function
cos	Cosinus
log	Natural logarithm
log10	Base-10 Logarithm
sin	Sinus
sqrt	Square root
tan	Tangent

Typically, your formula will contain references to other sources of data, such as measurement functions of IR images. To select a data source, click the **Connect** button. A dialog box will appear. Select the **Object** and **Value**, and click **OK**. This will insert a reference address into your expression. The address will be substituted with the actual value when the formula is used.

For the example above, with the spot and area items, you would do the following to add a formula that is defined as the subtraction of the spot temperature and the area's average temperature:

- Type a suitable label for the formula in the **Label** field, such as **Spot – Area**
- Click the **Connect** button. Select **Spot** from the **Object** list and **Temperature** from the **Value** list and click **OK**. This will insert the address **{sp1.value}** into your expression.
- Click the button labelled **–**. This will insert a minus sign into your expression.
- Again, click the **Connect** button. This time, select the **Area** from the **Object** list and **Average temperature** from the **Value** list and click **OK**.

Your expression should now read **{sp1.temp} – {ar1.avg}**.

You may also specify the precision of the formula, i.e. the number of decimals with which the result of the formula will be displayed. Do this by selecting the appropriate value from the **Precision** list. You can use 0–5 decimals.

To prevent the formula from presenting its result in the result table, select **Hidden result**.

Once finished, click the **OK** button. This brings you back to the **Formulas** dialog box. To add more formulas, repeat the procedure.

Another interesting formula you could try, is

({sp1.temp}^4) * 5.57033e-8 / 3.141592 [W/m^2/sr]

which calculates the blackbody radiance, when the temperature is in Kelvin. (**5.57033e-8** means 5.57033 x 10^{-8})

The command **Change** gives you the opportunity to change a defined formula. Selecting a formula is done by clicking on it. Double-clicking it will open the **Change Formula** dialog box directly. The **Delete** button removes the selected formula.

NOTE: Any text that follows the expression will be displayed, as is, in the field connected to the formula. For instance, your expression may be **{sp1.value} * {dobj} meters**.

6.8.7 Removal of analysis tools

You remove analysis tools by clicking the removal tool in the analysis tool box down, i.e. the red X. You then move the mouse to an analysis tool and click to remove it. All analysis tools including line cursors and isotherms can be removed in this way.

If you happen to click this button by mistake, click on it again to deactivate the function.

In the **Image** menu, there is a command that will remove all the active analysis tools (formulas excluded) at once. All the active formulas may be removed by a separate command in the **Image** menu.

6.8.8 Analysis tool styles and object parameters

You can affect the way in which analysis tools appear in the image. You can also change some of the object parameters used. Click this button to bring up the **Image Settings** dialog box or select **Settings** from the **Image** menu:.

10423803;a2

Figure 6.44 **Image settings** toolbar button

The **Analysis** tab looks like this:

10427603;a1

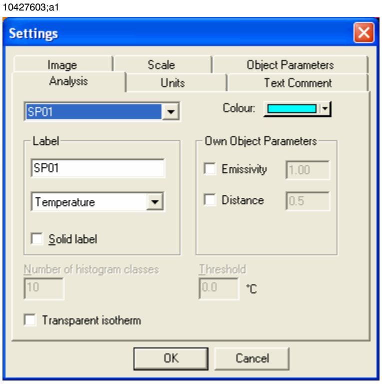


Figure 6.45 Analysis tab of the **Image settings** dialog box

First, use the list in the top left corner of the dialog box to select the appropriate analysis tool.

Then, write some short descriptive name in the text field below, unless you think that LI01 will do. This text will be shown beside the analysis symbol.

Further down the dialog box, there is a list box that allows you to display one measurement result beside the analysis symbol.

If you click in the **Solid label** box, the text beside the symbol will be displayed on a black background. This increases the visibility but hides more of the image.

You can also change the color of the analysis symbol, in case it happens not to be visible enough.

Frequently, the object emissivity or distance is varying between different parts of the IR image. All analysis tools (except the isotherm) can be forced to use their own values on these object parameters. Click in the box to the left of the parameter to enable the function and fill in the desired value to the right. The value shown before was the corresponding value of the object parameters of the image.

SEE ALSO: For more information about threshold, see section:

- 6.11.2 – Using a threshold on page 76

You may change more than one analysis function before clicking **OK**.

6.8.9 Emissivity calculation

The emissivity factor of an object can be calculated if you know its temperature and the temperature value is well above or below the ambient temperature.

Put for instance a box area on the object for which you know the temperature. Select **Emissivity Calculation** from the right mouse button menu of the area.

Enter the known temperature and click on **Calculate** to view the new emissivity. Click **OK** to accept and apply the new emissivity to the area.

10427703;a1

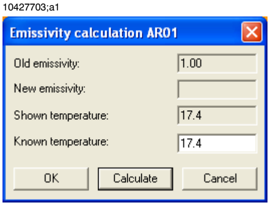


Figure 6.46 Emissivity calculation dialog box

6.8.10 Result table window

The result table presents measurement data from the IR image and from the analysis symbols. You can switch on/off the presentation of specific values from the settings dialog box reached by the right hand mouse button of the mouse.

6.8.10.1 Analysis tab

10424103;a1

Analysis | Position | Obj. Par | Image | Text comment

Label	Value [°C]	Min	Max	Max - Min	Avg	Stdev	Result	Expression
Image		32.0	105.6	73.6				
SP01	65.5							
SP02	102.6							
LI01		36.3	100.6	64.3	73.0	17.6		
AR01		60.5	101.5	41.0	83.7	10.1		

Figure 6.47 Analysis tab of the result table

Analysis symbols having their own object parameters have their labels marked with an asterisk.

If the difference temperature option is available and selected in the settings dialog box, then the reference temperature is displayed on the first line in the **Temp**. column. Results affected by the reference temperature are displayed on two lines, one line subtracted by the reference temperature and the other one as usual.

The expression and result columns present formulas and the result values.

6.8.10.2 Position tab

This tab shows the coordinates for spots, lines and areas. All coordinates are relative to the IR image top left corner. For a polygon area, the coordinates are those of a circumscribed rectangle.

10424203;a1

Analysis | Position | Obj. Par | Image | Text comment

Label	Pos X1	Pos Y1	Pos X2	Pos Y2
SP01	120	31		
SP02	206	96		
LI01	43	89	235	57
AR01	148	116	251	158

Figure 6.48 Position tab of the result table

6.8.10.3 Object parameter tab

The IR image object parameters are always displayed according to the settings dialog box. Analysis symbols having their own object parameters are also shown. Their labels are marked with an asterisk.

10424303;a2

Analysis | Position | Obj. Par | Image | Text comment

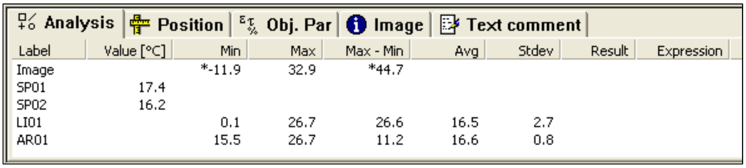
Label	Emis.	Distance	Refl. Temp.	Atm. Temp.	Atm. Trans.	Hum.	Ext. Opt. Temp.	Ext.
Image	1,00	0,5 m	24,0	24,0	0,99	50%	24,0	

Figure 6.49 Object parameter tab of the result table

6.8.10.4 Image tab

The image tab shows IR image data. From the settings dialog box, select a set of data to be shown.

10430103;a1



Label	Value [°C]	Min	Max	Max - Min	Avg	Stdev	Result	Expression
Image		*-11.9	32.9	*44.7				
SP01	17.4							
SP02	16.2							
LI01		0.1	26.7	26.6	16.5	2.7		
AR01		15.5	26.7	11.2	16.6	0.8		

Figure 6.50 Image tab of the result table

6.8.10.5 Text comments tab

The text comments tab shows the text comments that are associated with the currently displayed image. The text comments that are applied to the images that you record are not displayed here until you replay the images.

10429803;a1

Figure 6.51 Text comments tab of the result table

The concept of text comments is based on two important definitions – *label* and *value*. The following examples explain what the difference between the two definitions is:

Figure 6.52 Definitions of label and value

Label (examples)	**Value (examples)**
Company	FLIR Systems
Building	Workshop
Section	Room 1
Equipment	Tool 1
Recommendation	Repair

6.8.11 Interpretation of *>< values

Sometimes, when you accidentally make measurements almost outside the calibrated range of a camera, or when you enter extreme object parameters, you will get ***s** in front of or replacing the desired values. You may also get > or < characters in front of the values. In all these cases you are out of range.

6.8.12 Transferring single results with OLE

If you want to see result values not shown on the IR image or to process the values in other programs, then you should use OLE. First you click this toolbar button, or select **Copy value** from the **Edit** menu:

10429903;a1

Figure 6.53 **Copy value** toolbar button

This will bring up the **Copy Value** dialog box:

10430003;a1

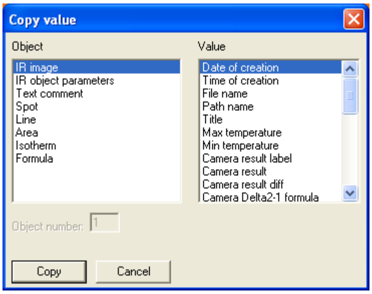


Figure 6.54 **Copy value** dialog box

Then, click in the left column on the appropriate type of object and fill in the ordinal number in the text box below. **SP01** corresponds to spot object 1. Click in the right column on the desired value.

Click **Copy** and this value can now be copied (or even linked) into other applications.

6.8.13 Transferring the result table with OLE

Click inside the result table window with the right hand mouse button and select **Copy**. In the receiving application, for example Microsoft® Excel, select **Edit Paste**. The whole result table is transferred.

6.8.14 Measurement output and units

You can select the temperature unit and distance unit you want the analysis tools to work with at the **Units** tab of the **Image Settings** dialog box that you bring up from the **Image** menu or with this button:

10424603;a2

Figure 6.55 **Image settings** toolbar button

The temperature unit is also used in the temperature scale.

10427803;a1

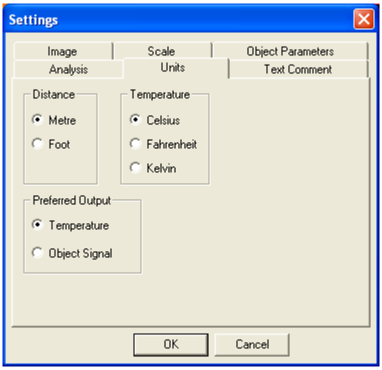


Figure 6.56 **Settings** dialog box

From the same dialog box, you can also set the preferred measurement output:

- The **Temperature** value is calibrated with a set of reference blackbodies.
- **Object signal** is a non-calibrated value approximately proportional to the amount of radiation sensed by the detector. It will change from camera to camera and between the measurement ranges.

6.8.15 Inheriting the analysis tools of cameras

Some versions of some cameras are equipped with analysis tools. When such a camera is electrically connected to ThermaCAM™ Researcher Professional, none of them are transferred to the PC, only the image. However, if there is a PC-Card hard disk in the camera, you can store images on it and move the PC-Card disk to the PC, open the images and in some cases get the analysis tools transferred. You only need to release the following button on the **Play images** toolbar in order to see the analysis tools stored in each image:

10424803;a2

Figure 6.57 Tool button used when inheriting analysis tools from camera

6.8.16 Studying whole images

Users of MatLab or Microsoft® Excel will find it convenient to be able to study images themselves. The selection **Save As** in the **Image** menu leads to a dialog box in which the current image can be saved in various formats:

- **MatLab** format, with one double precision value for each element of the image
- **FLIR Public Format** file format, with one single precision value for each element of the image
- **BMP** (bitmap) format, with or without analysis. Can only be used to view the images.

- **CSV** (comma separated value) format. The temperatures of the whole image is stored in a text format that Microsoft® Excel can read. The character that separates the temperatures in the file is fetched from the Windows regional settings.
- **SAF** (Standard Archive Format) was created for flexible and extensible use in data archiving. Although the data may be in ASCII or one or several binary formats, the file header is plain ASCII text and therefore human readable.

SEE ALSO: For more information, see section:

- 6.8.17 – Studying whole images with MatLab on page 64
- 6.8.18 – FLIR Public image format on page 65

There is also the **Save Tab As** command in the **File** menu, which saves the current tab (i.e. both the image and the adjacent graphs) as a bitmap file.

6.8.17 Studying whole images with MatLab

6

ThermaCAM™ Researcher Professional uses a simple MatLab matrix format. The binary file begins with five 4-byte integers structure. This is how it is described in C++:

```
typedef struct {  // MatLab file header (level 1.0)
   long type;     // 0 Intel type
   long mRows;    // Image height
   long nCols;    // Image width
   long imagF;    // 0 No imaginary part
   long namLen;   // Length of the matrix name + 1
} MatLabHeader;
```

This is followed by the name of the matrix, which corresponds to the name of the .mat file. This name must begin with a letter and not contain any strange character for MatLab to be able to read the file. In MatLab 7, this name can not have more than 7 characters.

The name is followed by nCols*mRows 8 byte double precision float numbers, each containing the current value of one point in the image, column by column.

```
XXXX(1,1):             Top left corner of the image
```

The image value matrix is followed by four extra one column matrices containing data about the stored image. Each matrix is preceded by a 20 byte Matlab header of the same format as the file header.

Example for image named XXXX.MAT:

```
typedef struct { // MatLab header (level 1.0)
long type; // 0 Intel type
long mRows; // 7 Matrix height
long nCols; // 1 Matrix width
long imagF; // 0 No imaginary part
long namLen; // 14 Length of the matrix name + 1
} MatLabHeader;
XXXX_DateTime(1,1):     Year
XXXX_DateTime(1,2):     Month
XXXX_DateTime(1,3):     Day
XXXX_DateTime(1,4):     Hour
```

```
XXXX_DateTime(1,5):     Minute
XXXX_DateTime(1,6):     Second
XXXX_DateTime(1,7):     Millisecond
typedef struct { // MatLab header (level 1.0)
long type; // 0 Intel type
long mRows; // 10 Matrix height
long nCols; // 1 Matrix width
long imagF; // 0 No imaginary part
long namLen; // 17 Length of the matrix name + 1
} MatLabHeader;
XXXX_ObjectParam(1,1):  Emissivity
XXXX_ObjectParam(1,2):  Object distance
XXXX_ObjectParam(1,3):  Reflected Temperature
XXXX_ObjectParam(1,4):  Atmospheric Temperature
XXXX_ObjectParam(1,5):  Relative Humidity
XXXX_ObjectParam(1,6):  Computed atm. transmission
XXXX_ObjectParam(1,7):  Estimated atm. Transmission
XXXX_ObjectParam(1,8):  Reference Temperature
XXXX_ObjectParam(1,9):  External optics temperature
XXXX_ObjectParam(1,10): External optics transmission
typedef struct { // MatLab header (level 1.0)
long type; // 0 Intel type
long mRows; // 9 Matrix height
long nCols; // 1 Matrix width
long imagF; // 0 No imaginary part
long namLen; // 13 Length of the matrix name + 1
} MatLabHeader;
XXXX_Scaling(1,1):      Blackbody range min
XXXX_Scaling(1,2):      Blackbody range max
XXXX_Scaling(1,3):      Type of output
                         0 = temperature
                         2 = difference temperature
                         4 = object signal
                         5 = difference object signal
XXXX_Scaling(1,4):      Camera scale min
XXXX_Scaling(1,5):      Camera scale max
XXXX_Scaling(1,6):      Calculated scale min
XXXX_Scaling(1,7):      Calculated scale max
XXXX_Scaling(1,8):      Actual scale min
XXXX_Scaling(1,9):      Actual scale max
typedef struct { // MatLab header (level 1.0)
long type; // 0 Intel type
long mRows; // 2 Matrix height
long nCols; // 1 Matrix width
long imagF; // 0 No imaginary part
long namLen; // 15 Length of the matrix name + 1
} MatLabHeader;
XXXX_FrameInfo(1,1):    Image number
XXXX_FrameInfo(1,2):    Trig count
```

6.8.18 FLIR Public image format

The "xxxx.fpf" files consist of a header followed by a matrix of single precision IEEE floating point values, each representing one point of the image.

A C-style description of the header layout can be found in the header file fpfimg.h, available in the Examples sub-directory of the installation.

The current version of the format is 2, in which:

- The xSize, ySize and ImageType fields are properly set.

- The spare fields are zeroized.
- The image point values are stored starting from the top left and row by row.

FPF images can only be saved by ThermaCAM™ Researcher Professional, not read.

The basic data types are:

Char	8 bit	Often represents ASCII characters, may represent an 2's complement 8 bit integer (-128 - +127)
Unsigned char	8 bit	8 bit integer number (0 - 255)
Short	16 bit	16 bit integer (2's complement)
Unsigned short	16 bit	16 bit integer
Long	32 bit	32 bit integer (2's complement)
Unsigned long	32 bit	32 bit integer
Float	32 bit	IEEE floating point number, sign + 23 bit mantissa + 8 bit exponent, Representing numbers in the range +/- 10^{38}
Char[<len>]	Len * 8 bit	ASCII character string, most certainly terminated with the NUL character (=0)
Int	32 bit	32 bit integer (2's complement)

Multiple byte data types are stored with the least significant byte first.

6.8.18.1 The whole header data structure (size 892 bytes)

```
typedef struct
{
   FPF_IMAGE_DATA_T  imgData;
   FPF_CAMDATA_T     camData;
   FPF_OBJECT_PAR_T  objPar;
   FPF_DATETIME_T    datetime;
   FPF_SCALING_T     scaling;
   long  spareLong[32];    /* = 0 */
} FPFHEADER_T;
```

6.8.18.2 The image data structure (120 bytes)

```
typedef struct
{
   char fpfID[32];                /*  "FLIR Public Image Format" */
   unsigned long  version;        /*  = 2 */
   unsigned long  pixelOffset;    /*  Offset to pixel values from
                                      start of fpfID. */
   unsigned short ImageType;      /*  Temperature        = 0,
                                      Diff Temp          = 2,
                                      Object Signal      = 4,
                                      Diff Object Signal = 5, etc */
   unsigned short pixelFormat;    /*  0 = short integer  = 2 bytes
                                      1 = long integer   = 4 bytes
                                      2 = float          = 4 bytes
```

```
                                                3 = double         = 8 bytes*/
   unsigned short xSize;
   unsigned short ySize;
   unsigned long  trig_count;       /* external trig counter */
   unsigned long  frame_count;      /* frame number in sequence */
   long  spareLong[16];             /* = 0 */
} FPF_IMAGE_DATA_T;
```

6.8.18.3 The camera data structure (360 bytes)

```
/*  String lengths    */
#define FPF_CAMERA_TYPE_LEN   31   /* Camera name string */
#define FPF_CAMERA_PARTN_LEN  31   /* Camera part number string */
#define FPF_CAMERA_SN_LEN     31   /* Scanner serial number string */
#define FPF_LENS_TYPE_LEN     31   /* Lens name string */
#define FPF_LENS_PARTN_LEN    31   /* Lens part number string */
#define FPF_LENS_SN_LEN       31   /* Lens serial number string */
#define FPF_FILTER_TYPE_LEN   31   /* Filter name string */
#define FPF_FILTER_PARTN_LEN  31   /* Filter part number string */
#define FPF_FILTER_SN_LEN     31   /* Filter serial number string */
typedef struct
{
    char camera_name[FPF_CAMERA_TYPE_LEN+1];
    char camera_partn[FPF_CAMERA_PARTN_LEN+1];
    char camera_sn[FPF_CAMERA_SN_LEN+1];

    float camera_range_tmin;
    float camera_range_tmax;

    char lens_name[FPF_LENS_TYPE_LEN+1];
    char lens_partn[FPF_LENS_PARTN_LEN+1];
    char lens_sn[FPF_LENS_SN_LEN+1];
    char filter_name[FPF_FILTER_TYPE_LEN+1];
    char filter_partn[FPF_FILTER_PARTN_LEN+1];
    char filter_sn[FPF_FILTER_SN_LEN+1];
   long  spareLong[16];             /* = 0 */
}FPF_CAMDATA_T;
```

6.8.18.4 The object parameters data structure (104 bytes)

```
typedef struct
{
   float emissivity;          /* 0 - 1 */
   float objectDistance;      /* Meters */
   float ambTemp;             /* Reflected temperature in Kelvin */
   float atmTemp;             /* Atmospheric temperature in Kelvin */
   float relHum;              /* 0 - 1 */
   float compuTao;            /* Computed atmospheric transmission */
   float estimTao;            /* Estimated atmospheric transmission */
   float refTemp;             /* Reference temperature in Kelvin */
   float extOptTemp;          /* Kelvin */
   float extOptTrans;         /* 0 - 1 */
   long  spareLong[16];       /* = 0 */
} FPF_OBJECT_PAR_T;
```

6.8.18.5 The date and time data structure (92 bytes)

```
typedef struct
{
   int Year;
   int Month;
   int Day;
   int Hour;
   int Minute;
   int Second;
```

```
   int MilliSecond;
   long  spareLong[16];            /* = 0 */
} FPF_DATETIME_T;
```

6.8.18.6 The scaling data structure (88 bytes)

```
typedef struct
{
   float tMinCam;          /* Camera scale min, in current output */
   float tMaxCam;          /* Camera scale max */
   float tMinCalc;         /* Calculated min (almost true min) */
   float tMaxCalc;         /* Calculated max (almost true max) */
   float tMinScale;        /* Scale min */
   float tMaxScale;        /* Scale max */
   long  spareLong[16];    /* = 0 */
} FPF_SCALING_T;
```

6.8.19 Studying parts of images

If one part of the image is particularly interesting, you can put any kind of area around it and save its temperatures in a text file that Microsoft® Excel can read. (.csv format)

6

This command is called **Save area as…**, and is available in the **Image** menu.

6.9 How to measure many images

The previous section was about measurements on single images. Much of what was said there is still valid and will not be repeated here. This section will deal only with questions arising when several images are involved. Typical examples are how a temperature varies with time or how two (or more) measurements vary together.

Two approaches can be used in achieving these measurements. Either you record images and extract the results while playing them back or you get the information directly from the live stream of images.

We recommend that you record images especially if the object you study is moving, since it can be a tedious task to track the moving object with the analysis tools. During the recording, you will have to aim and mind the camera focus as well.

6.9.1 Making measurements in playback

While recording, you often find that the conditions change. It is quite natural to improve the temperature scale or the ambient temperature value while the recording is in progress. This information is stored in the recorded images and can be retrieved during the playback.

Of course you can change the scale and the object parameters even when playing the images. Then you can choose among the following temperature scales:

- The original scale of the recorded image, the source scale
- A calculated scale, automatically adjusted to the image
- A fixed scale

This is controlled by one button on the **Standard** toolbar and one on the **Play images** toolbar:

10424903;a2

Figure 6.58 **Candle** toolbar button

10425003;a2

Figure 6.59 **Lock scale** toolbar button

If you click on the candle, it will become depressed and a new scale will automatically be calculated for every new image as you play them. If you click again on the candle releasing it or, if you click the **Lock scale** button, the current scale limits will be locked (kept) for every new image. If you release the right button by clicking on it again, the original scale of the images is shown.

If you change the scale manually, and forget to click the lock scale button afterwards, you will be asked **Do you want to use your new scale for all images?**

The following options exist for the object parameters:

- The original parameters of the recorded images
- New, enforced object parameters

This is also controlled from the play recording tools, using this button:

10425103;a2

Figure 6.60 Button used to change object parameters

If it is depressed, the current object parameters are kept for all new images. If it is released, the original object parameters of the images are used.

If you change the object parameters manually, and forget to click the **Lock object parameters** button afterwards, you will be asked **Do you want to use your new object parameters for all images?**

The images recorded by ThermaCAM™ Researcher Professional do not contain any analysis tools. Hence, you have to add them while playing the images. This is very well, as long as the object of interest stands still. You simply add the analysis and save it with the session file.

Should the object be moving, we recommend going through the images one by one, moving/reshaping the analysis tools for each image, and saving them under the same name. Thus, forcing each image to contain its own set of analysis tools. There is a **Save As** item in the **Image** menu that will do the job.

	In order to make ThermaCAM™ Researcher Professional bother about the analysis of these images in the future, you have to release the **Lock analysis symbols** button for this session.
	It is also possible for you to “lock” the zoom factor, if you like. Each image can contain a different zoom factor. By pressing this button, you keep the same for all images.

If you change the zoom factor manually, and forget to click the lock zoom factor button afterwards, you will be asked **Do you want to use your new zoom factor for all images?**

6.9.2 Plotting and logging measurement results

Plotting is useful when you wish to illustrate temperature variation over time. Just look at this graph which shows the temperature decline and increase of a hot and a cold cup of water.

10425403;a1

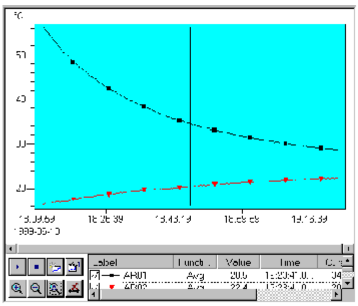


Figure 6.61 Graph showing temperature development in a hot and cold cup of water

	To get such a plot, you would add two areas to the live image, switch to the **Plot** tab and click on this button beside the plot table. Use it to add the average result of the two areas to the plot graph. Most analysis tools, including results from formulas, can be added.
	Click this button to stop the plotting.
	Click this button to enable the plotting.

NOTE: Plotting always stops when analysis tools are added to the plot.

Click on **AR01** in the plot table, which will highlight the line. If you click with right mouse button on the line, a menu appears from which you can select **Conditions**. This is the dialog box that will appear:

10425803;a1

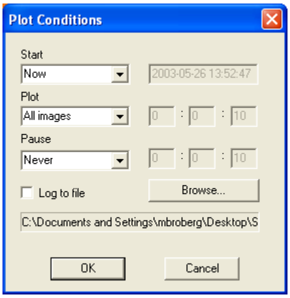


Figure 6.62 Plot conditions dialog box

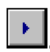
Here you can control the way each result series is plotted. Set a starting time a few minutes ahead and an interval of 20 seconds for both areas. If you have connected an external trig, you might use that start condition instead. Click **OK**.

SEE ALSO: For more information about how to connect an external trig, see section:

- 6.4 – How to trigger ThermaCAM™ Researcher Professional from outside on page 33

If you select the **Log to file** check box, the results will be saved in a log file (.irp) too, in text format (see section 6.9.2.1 – The Plot/log file format on page 72). You can read such files back into the plot window for examination later, if you like.

Use the remaining seconds until the plotting starts to clear the graph by clicking with the right mouse button on it and by selecting **Clear** from the menu.

Remember to enable the plotting by clicking the start button .

When the starting time arrives, the plotting will start and continue until you click the stop button again, unless you had set some condition that causes the plot to stop earlier.

To inspect the plotted results, place a cursor on the graph and read the results from the cursor column of the plot table. Click with the right mouse button on the graph and select **Cursor** from the menu. You can catch and drag the cursor with the left mouse button.

	If you have plotted many results at the same time, you will find it convenient to temporarily hide some of them by clicking on this symbol on the corresponding line of the plot table.
	To inspect the graph in more detail, zoom in and out using these three buttons. The A button auto-zooms so the data will fill most of the graph window. If a particular part of the graph is more interesting, you zoom into that part by "painting it" with the mouse. Hold the left mouse button down while you move the mouse over the interesting part of the graph.

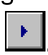
	To inspect the graph while plotting still is going on, click this button. It will prevent the plotting window from auto-scrolling to the end as soon as new results arrive.
	The scaling of the axes and many other settings such as colors and line widths can be changed if you bring up the settings dialog box with this button.

To save plot data in text format either log it while it is being plotted (as described above) or click with the right mouse button on the line in the plot table and choose **Save** from the menu. The file format is described in section 6.9.2.1 – The Plot/log file format on page 72.

If you intend to make long plottings, there are a few things worth considering:

- Eventually, the plotting on the screen will slow down the computer. You can avoid this by switching off the auto-scrolling and have the function plot outside its window. Then, you won't see the whole graph until the plotting is finished.
- The temperature drift of the camera is important during long plottings. No camera will be perfectly stable, but you can improve the situation by running it until it reaches a steady state.

If you want to make plottings from images stored on disk, do like this to get the first image included in the plot:

1. Open the images via the **Image** menu. Place your analysis tools on the first image
2. Add the tools to the plot table
3. Set appropriate settings for this plot
4. Press the start button .
5. Open the images once again, or clear the graph
6. Play the images forward (backward plotting is not supported)

6.9.2.1 The Plot/log file format

The results of plots and loggings are stored as text in .irp files.

In this sample, the area 1 average temperature has been plotted for three images. On the first line `Type=2, Number=1` means area 1, `Value=4` means average and `IROutput=0` means temperature.

```
Type=2 Number=1 Value=4 IROutput=0
305.558 1094482928.289     0     9/6/2004 5:02:08.289 PM     0     1
305.555 1094482928.332     0     9/6/2004 5:02:08.332 PM     0     2
305.555 1094482928.389     0     9/6/2004 5:02:08.389 PM     0     3
```

The following lines all have have 7 columns separated by a tab character (#9).

1. The value, in this case a temperature. Temperatures are always in Kelvin.
2. A decimal time stamp with milliseconds

3 The validity of the value (0 = OK, 1 = Warning, 2 = Underflow, 3 = Overflow, 4 = Invalid.)
4 The date in Windows format
5 The time in Windows format
6 The trig counter
7 The plot counter

6.9.3 Transferring plot data using OLE

You can also right click inside the plot window and select **Copy**. When pasting, choose either **Text or Picture (Enhanced Metafile)**. The **Text** option copies the plot table contents and the **Picture** option copies the entire plot window in graphical format.

6.9.4 Transferring many image results with OLE

If you want to study really intricate things, like plotting the difference between two temperatures over time or correlating a temperature to some other entity, such as pressure, then you have to you use a spread sheet program capable of handling OLE. Assuming that you have access to Microsoft® Excel, you should proceed like this.

Embed ThermaCAM™ Researcher Professional in a spreadsheet (**Insert** → **Object** → **ThermaCAM™ Researcher Professional Session**) and write an Microsoft® Excel macro in VBA (Visual Basic for Applications). It will open the right session file in ThermaCAM™ Researcher Professional and, in a loop, read the desired measurement values from each image and put them in a pair of columns of cells. Then use the chart wizard of Microsoft® Excel to create a graphical presentation.

Here is an example of such a VBA macro:

```
Sub PlaySequence_Click()
    Dim sess As Object
    Dim row As Integer
    Dim col As Integer
    row = 1
    col = 10
    ' Get a reference to the ThermaCAM™ Researcher Professional object
    Set sess = _
       Worksheets("Sheet1").OLEObjects("Object 1").Object
    ' Move to the first image in the session
    sess.GotoFirstImage

    ' Start a loop that iterates through all images
    ' in the session
    Do While True
        ' Store IR image time and spotmeter temperatures
        ' in the cells
        Worksheets(1).Cells(row, col).Value = _
           sess.GetNamedValue("sp1.temp")
        Worksheets(1).Cells(row, col + 1).Value = _
           sess.GetNamedValue("sp2.temp")
        ' Leave col + 2 for the difference sp02 - sp01
        '
        Worksheets(1).Cells(row, col + 3).Value = _
```

```
            sess.GetNamedValue("time")

         If sess.IsLastImage Then
           Exit Do
         End If
         ' Load next image in the session and
         ' increment the row counter
         sess.StepForward
         row = row + 1
    Loop
End Sub
```

6.10 How to study temperature profiles

6.10.1 Obtaining a profile

Temperature profiles are useful when you wish to illustrate the temperature variation across or along an object in the image. You just have to put the line on the image and switch to the profile window in order to be able to see the profile. Below the graph, there is a table, in which you can get interesting information about each line.

10426303;a1

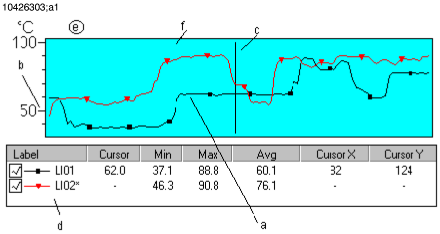


Figure 6.63 A temperature profile (example)

Figure 6.64 Explanations of callouts

a	Profile	d	Profile table
b	Temperature scale	e	Chart area
c	Line cursor	f	Plot area

If you would like to change the way in which the profiles are displayed, you can do this by the **Settings** dialog box, available on the right hand mouse button when you click on top of the profile.

The profile scale is normally connected to the IR image scale, but can be set independently or automatically.

The line presentation can be reversed, in case you happened to draw the line in the wrong direction.

Each line can have a cursor, which is displayed both in the profile window and the IR image. When you need to find the image position of a certain "bump" in the profile, add a cursor tool to the line and move it in the IR image until it hits the bump.

6.10.2 Transferring temperature profile data using OLE

The profile of each line or area is available in table form if you select **String data** for a line from the **Copy Value** dialog box of the **Edit** menu. In the receiving application, for example Microsoft® Excel, select **Edit** → **Paste Special**.

You can also right click inside the profile window and select **Copy**. When pasting, choose either **Text** or **Picture (Enhanced Metafile)**. The **Text** option copies the profile table contents and the **Picture** option copies the entire profile in graphical format.

6.11 How to study temperature distributions

6.11.1 Obtaining a histogram

The easiest way to assess the distribution of temperatures within an area or along a line on the image is to look at the histogram, which displays how much of the area/line that is occupied by a certain temperature interval. You simply put the area/line on the image and switch over to the histogram window. Below the bar graph, there is a table, in which you select which analysis tool to display.

10426403;a1

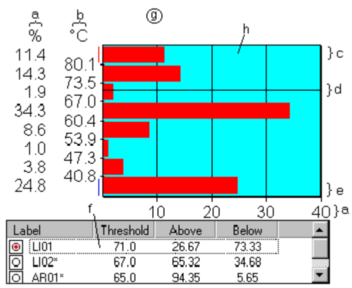


Figure 6.65 A histogram (example)

Figure 6.66 Explanations of callouts

a	The percentage value for each class	e	Underflow class, marked by a blue line by the scale
b	Class temperature limits	f	Histogram table, indicating the active histogram
c	Overflow class, marked by a red line by the scale	g	Chart area
d	Threshold indicator	h	Plot area

If you would like to change the number of class intervals or the top/bottom limit of the histogram scale, this can be done by the **Settings** dialog box, available on the right hand mouse button when you click on top of the histogram. The permitted number of classes is 2–64.

The histogram scale is normally connected to the IR image scale, but can be set differently. Changing this does not, however, change the class interval limits that always are determined by the current IR image scale.

Those parts of the area/line that fall outside the IR scale are included in the overflow/underflow classes.

If you want to be able to see and compare two histograms at the same time you must switch the histogram window over to dual histogram mode. Afterwards, you can select two analysis tools for display at the same time.

6.11.2 Using a threshold

Let's suppose that you are not interested in the full temperature distribution of a line/area, just in getting to know how much of it that has been sufficiently heated or cooled. Then the threshold function will suit your purpose.

You can associate a threshold with a line/area from the **Analysis** tab of the IR image settings or the **General** tab of the **Histogram** window Settings and obtain the desired percentage from the **Result Table** window or the **Histogram** window, if you switch on its presentation. The threshold can also be displayed in the histogram bar graph.

Temperatures that are equal to the threshold temperature are counted as below the threshold.

The threshold does not have to coincide with any class limit of the histogram window.

6.11.3 Transferring temperature distribution data using OLE

The histogram of each line or area is available in table form if you select **Histogram** from the **Copy Value** dialog box of the **Edit** menu. In the receiving application, for example Microsoft® Excel, select **Edit** → **Paste Special**.

You can also right -click inside the histogram window and select **Copy**. When pasting, choose either **Text** or **Picture (Enhanced Metafile)**. The **Text** option copies the histogram table contents and the **Picture** option copies the entire histogram in graphical format.

7 Menu commands

7.1 File menu

This menu contains commands related to session files. You can create new sessions, open existing session files, save the current session, select a default session, open/add images to the current session, print an image and leave the program. You can also save the current tab as a bitmap file.

SEE ALSO: For more information, see sections:

- 5.5 – Session files on page 13
- 6.6.1 – Open images dialog box on page 40

7.2 Edit menu

This menu contains commands related to the clipboard.

SEE ALSO: For more information, see sections:

- 6.3.2 – Transferring an IR image with OLE on page 33
- 6.8.12 – Transferring single results with OLE on page 62
- 12.1 – OLE in brief on page 101
- 6.6 – How to play back images on page 39

7.3 View menu

This menu lists all the toolbars, the control panels and the status line of ThermaCAM™ Researcher Professional. Use this menu to hide and unhide them as you please.

SEE ALSO: For more information about tools and toolbar buttons, see section:

- 5.6 – Program screen layout on page 14

7.4 Camera menu

This menu contains a number of commands related to the connecting and controlling of the camera.

SEE ALSO: For more information about connecting and controlling the camera, see section:

- 6.2 – How to connect and control the camera on page 22

7.5 Image menu

This menu leads to most commands related to the handling of single images.

SEE ALSO: For more information, see sections:

- 5.4 – Image directory on page 13
- 6.6.1 – Open images dialog box on page 40
- 6.3.1 – Obtaining a good IR image on page 30
- 6.8.14 – Measurement output and units on page 62
- 6.8.16 – Studying whole images on page 63
- 6.8.7 – Removal of analysis tools on page 58
- 6.8.19 – Studying parts of images on page 68
- 6.8.9 – Emissivity calculation on page 59

7.6 Recording menu

This menu contains commands about the recording of images and the playback of recordings.

SEE ALSO: For more information, see sections:

- 6.5 – How to record IR images on page 34
- 6.6 – How to play back images on page 39
- 6.7 – How to edit/convert sequences on page 44

7.7 Help menu

This menu provides you with access to the ThermaCAM™ Researcher Professional help file, which happens to correspond to this manual, and with version information about ThermaCAM™ Researcher Professional and its components, the IR image control program and the camera control program.

7.8 Play Images toolbar menu

This menu pops up when you click with the right mouse button on the play images tool bar. It contains some of the commands in the **Recording** menu.

SEE ALSO: For more information, see sections:

- 6.6 – How to play back images on page 39
- 6.7 – How to edit/convert sequences on page 44

7.9 IR Image window menus

These menu pops up when you click with the right mouse button on the IR image.

If you happen to click near an analysis symbol, you will get a menu for that symbol. If you click anywhere else on the IR image, you will get a menu with some of the commands from the IR menu.

SEE ALSO: For more information, see sections:

- 6.6.1 – Open images dialog box on page 40
- 6.3.1 – Obtaining a good IR image on page 30
- 6.8.14 – Measurement output and units on page 62
- 6.8.16 – Studying whole images on page 63
- 6.8.7 – Removal of analysis tools on page 58
- 6.8.19 – Studying parts of images on page 68
- 6.8.9 – Emissivity calculation on page 59

7.10 Results table window menu

This menu pops up when you click with the right mouse button on the **Results** table window. It contains settings for the **Results** table.

SEE ALSO: For more information about the result table, see section:

- 6.8.9 – Emissivity calculation on page 59

7.11 Profile window menu

This menu pops up when you click with the right mouse button on the profile window. It contains settings for the profile window.

SEE ALSO: For more information about the profile, see section:

- 6.10 – How to study temperature profiles on page 74

7.12 Histogram window menu

This menu pops up when you click with the right mouse button on the histogram window. It contains settings for the histogram window.

SEE ALSO: For more information about histogram, see section:

- 6.11 – How to study temperature distributions on page 75

7.13 Plot window menu

This menu pops up when you click with the right mouse button on the plot window. It contains settings for the plot window.

SEE ALSO: For more information about plotting, see section:

- 6.9.2 – Plotting and logging measurement results on page 70

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8 FireWire™ configuration

8.1 *System parts: ThermaCAM™ S- and ThermoVision™ A-series – FireWire™ interface*

This configuration is used for the following camera models:

- ThermaCAM™ S60
- ThermaCAM™ S65
- ThermaCAM™ S40
- ThermaCAM™ S45
- ThermaCAM™ SC640
- CPA 8200
- CPA 8000
- ThermoVision™ A20 M FireWire™
- ThermoVision™ A40 M FireWire™

10430403;a2

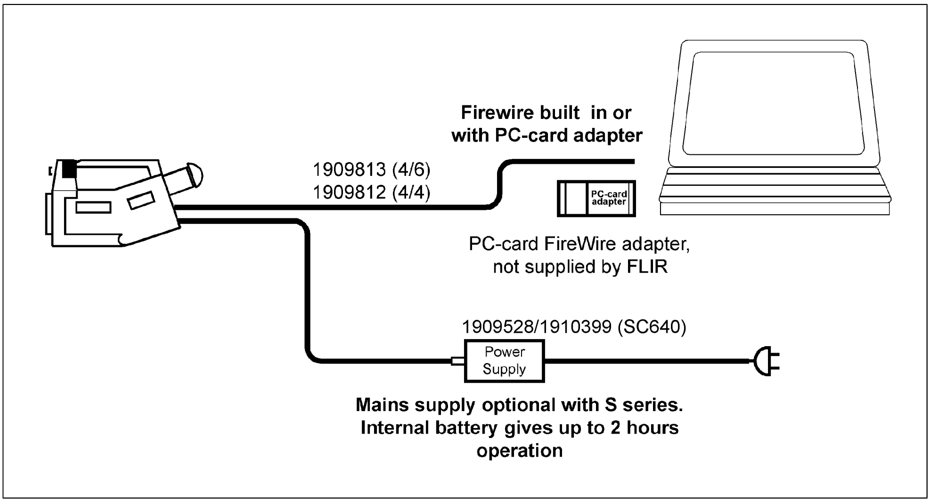

Figure 8.1 ThermaCAM™ S-series – FireWire™ interface & laptop computer

10430503;a2

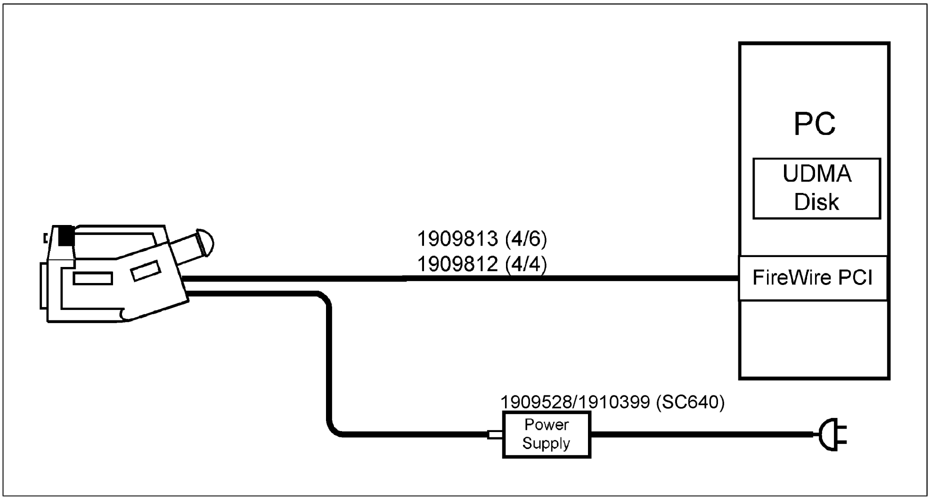

Figure 8.2 ThermaCAM™ S-series – FireWire™ interface & desktop computer

10430603;a1

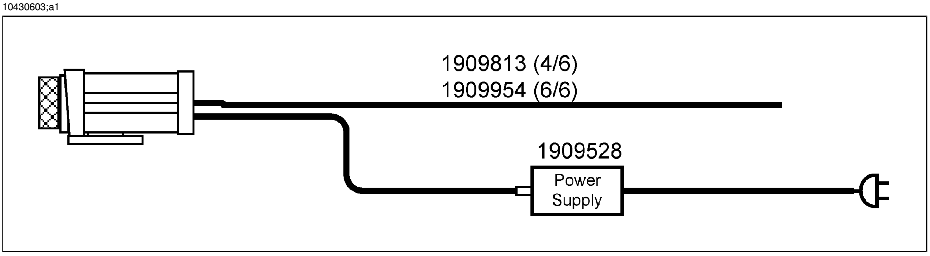

Figure 8.3 ThermoVision™ A-series – FireWire™ interface

Necessary parts:

- A FireWire™ cable, 6 pole/4 pole, max 4.5 m / 14.8 ft.
- A power supply (the camera battery can also be used)
- An optional FireWire™ hub, to be able to add a 6 pole/6 pole extension cable
- ThermaCAM™ Researcher Professional CD-ROM (not shown), including PC driver software and Direct X

8.2 Software limitations

The FireWire™ configuration works on Windows® 98 (second edition), Windows® ME, Windows® 2000, Windows® XP, and Windows® Vista operating systems (SC640 only on Windows® 2000/XP/Vista).

In Windows® 98/ME, due to file system limitations, you can not get full burst recording rate.

In Windows® 2000/XP/Vista, full burst rate recording of the cameras is only possible when the target disk is formatted with a NT file system (NTFS) and is fast enough.

8.3 PC recommendations

To get a reasonably high performance you should have a Pentium desktop computer with a clock rate of 1 GHz or more.

If IDE Ultra DMA/100 is supported on your computer, then there is no need for striped SCSI disks. There are such disks that are so fast that you don't need to use striped volumes. We now recommend 7200 RPM 30 GBUltra DMA/100 disks (or better). Your computer not only has to support this technology, you also have to have service pack 2 of Windows® 2000 (or Windows® XP/Vista) to make it work.

If you have a serial ATA disk (SATA) that is even better.

The FireWire™ adapter in the PC must conform to the 1394a-2000 specifications and must support bus speeds up to 400 Mb/s.

DirectX 8.1 (or higher) is required for the FireWire™ configuration.

The amount of memory in the PC should be at least twice the Microsoft® recommendation.

Our recommendation is to set the color palette to 256 colors. TrueColor gives a lower frame rate, but better color fidelity.

8.4 Installing the FireWire™ camera driver software

8.4.1 General instructions

Step	Action
1	If needed, insert a FireWire™ Adapter into a free PCI bus slot on your desktop PC. The adapter must conform to the IEEE-1394a-2000 specification and be capable of supporting a serial bus speed of 400 Mb/s. Windows® should automatically detect the new hardware and ask for its drivers, which are supplied by the FireWire™ Adapter manufacturer
2	Disable any sensitive equipment (especially disks), that you may already have connected to your FireWire™ adapter.
3	If you have Windows® 98, make sure that the ThermaCAM™ Researcher Professional software is installed first.
4	Switch on the camera and check that the camera has the Digital Video Mode setting DCAM before you plug it into your computer. SC640 does not have this setting.
5	Connect the 1394 cable between the camera to the FireWire™ adapter of the PC when the camera is up and running.

8.4.2 Windows Vista

Step	Action
1	Please log in as Administrator during this installation. Windows® should detect the camera, after a while.
2	If Windows® displays a **New Hardware Found** Wizard for the device **FLIR ThemaCAM**, select **Locate and install** and **Don't search online**. Either insert the ThermaCAM™ Researcher Professional CD-ROM or select **Don't have the disk** and **Browse my computer** to let Windows® find an appropriate driver on the CD or in your C:\Program Files\Flir Systems\Device drivers directory.
3	Please allow Windows® to continue installing the software despite the complaints about the FLIR drivers not being digitally signed. If Windows® refuses to let you do this, please check that the Windows® Update Driver setting (Right-click on My Computer -> Properties -> Hardware tab) is not set to **Never**.
4	Some cameras will also contain a FLIR 1394 Network Adapter device. You can install it in the same way, if you like. ThermaCAM™ Researcher Professional does not use it.

8.4.3 Windows 2000/XP

Step	Action
1	Log in as Administrator. Windows® should detect the camera after a while.
2	If Windows® displays a **New Hardware Found Wizard** for the device FLIR ThemaCAM, either let Windows® search for the best available driver or select **Install from a specific location (Advanced)** to let Windows® find an appropriate driver in your “C:\Program Files\Flir Systems\Device drivers” directory.
3	Allow Windows® to continue installing the software despite the complaints about the FLIR drivers not being digitally signed. If Windows® refuses to let you do this, please check that the Driver Signing setting (Right-click on **My Computer** → **My Computer** → **Properties** → **Hardware** tab) is not set to **Block.**

8.4.4 Windows 98SE/ME

Step	Action
1	Have your Windows(TM) 98/ME system CD available.
2	Windows® should detect the camera after a while.
3	If nothing seems to happen, and the ThermaCAM™ appears in the Device Manager category **Other devices** (Right click on **My Computer** → **Properties** → **Device Manager** tab), click on the failing ThermaCAM™ device name and press the Remove button. Un-plug and plug the camera cable back into the FireWire™ adapter to make the ThermaCAM™ re-appear as an “Imaging device”.

Step	Action
4	When Windows® starts asking you for files, please follow the instructions on the screen. Browse to your Windows® CD for Windows® files and to “C:\Program Files\Flir Systems\Device drivers” for the flirdcam.sys file and click **Next.**

The FLIR Systems device drivers can also be found on the ThermaCAM™ Researcher Professional CD-ROM, if you find that more convenient.

There are cameras capable of supporting other devices, such as the FLIR 1394 Network Adapter and the FLIR USB Adapter. These devices belong to the ThermaCAM™ Connect 3.0 or ThermaCAM™ QuickReport product, which has drivers for them.

You do not have to install these drivers to make ThermaCAM™ Researcher Professional work.

8.5 Troubleshooting the FireWire™ installation

To work properly, the FireWire™ configuration needs:

- Microsoft® Windows® 98 (sec ed), ME, 2000, XP or Vista
- Direct X 8.1 (or higher)
- A successful installation of ThermaCAM™ Researcher Professional
- A correct **Type of camera** and **Type of connection** setting in the **Select Camera** dialog.
- A 6 (or 4) to 4 FireWire™ cable for ThermaCAM™ S-series
- A 6 (or 4) to 4 FireWire™ cable for ThermaCAM™ SC640-series
- A 6 (or 4) to 6 FireWire™ cable for ThermoVision™ A-series
- A IEEE-1394a-2000 FireWire™ adapter
- A successful installation of the FireWire™ Adapter driver
- A camera equipped for FireWire™ digital output with its digital video mode set to DCAM
- The Driver Signing setting of the Windows® Device Manager should not block unsigned files (Windows® 2000, XP, Vista)
- The TCP/IP protocol Automatic Metric setting should not be set
- A successful installation of the FLIR ThermaCAM™ camera driver for each camera used
- If two (or more) cameras are used, they have to have the same image frame rate setting if manufactured before July 1st, 2003
- A 1GHz (or faster) PC or laptop equipped with a IEEE-1394a-2000 interface capable of serial bus speed of 400 Mb/s.
- Recent updates from Microsoft® and the computer manufacturer
- With Windows® XP Service Pack 2, S series cameras must have filekit 2.2.5 (or higher) and A series cameras must have filekit 1.2.12 (or higher). The FLIR ThermaCAM™ driver must have version 5.20.2600.923 (or higher).

- Administrator rights (or a change in the Local Security Policy) for the users that plug in/out the camera on Windows® 2000/XP
- Proper settings if you have a firewall in your computer.
- That ThermaCAM™ Connect 2.0 is not connected to the camera
- Acrobat Reader from http://www.adobe.com

Some laptop computers are not equipped with the correct FireWire™ interface. In such cases, a proper FireWire™ interface can be added using a CardBus interface adapter. A desktop PC needs a free PCI slot in order to install a FireWire™ interface card. The FireWire™ connector of your PC may have 4 or 6 pins.

The IEEE-1394a-2000 adapter must be capable of a serial bus speed of 400 Mb/s in order to achieve full real time recording speed (50/60Hz). Even when this is the case, limitations elsewhere in the computer may not allow full speed.

With some laptop chipsets there is a problem cause by too much latency in the C3 power state transition which cause buffer underruns. This can be cured by a change in the Windows® registry. For more information, see Publ. No. T559004, Installation Hints, on the CD-ROM.

Since FireWire™ is a fairly recent addition to the Windows® world, hardware and software weaknesses still plague the technology. We recommend that you visit the Microsoft® Windows® Update website (windowsupdate.microsoft.com) to refresh your software and Windows® drivers, and that you visit the corresponding site of your computer manufacturer to receive its latest updates.

Some Windows® versions don't support FireWire™ interface cards. You cannot use the FireWire™ interface on Windows® 95, 98 (first edition) and NT 4.0.

Do not connect other FireWire™ equipment to your computer when you transfer IR images.

Please disable any sensitive equipment (especially disks) that you may already have connected to your FireWire™ adapter before you plug in the camera.

SEE ALSO: For more information, see the following documents on the CD:

- Installation Hints (Publ. No. T559004)
- System configurations (Publ. No. 1 557 783)

9 Gigabit Ethernet interface configuration

9.1 System parts: Gigabit Ethernet interface

This configuration is used for the following camera models:

- Merlin uncooled microbolometer
- Merlin NIR (InGaAs)
- Merlin QWIP
- Merlin MID (InSb)
- Omega UL3 uncooled microbolometer
- Phoenix with RTIE
- ThermoVision™ A320G

10570003;a3

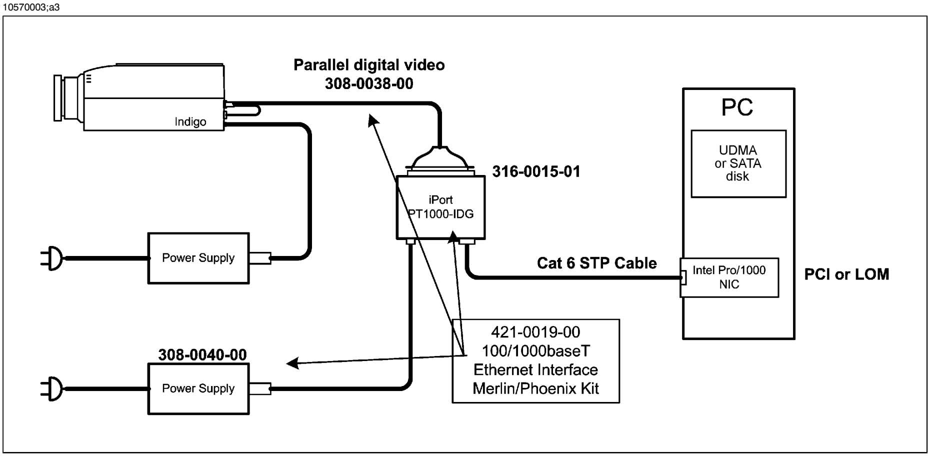

Figure 9.1 ThermaCAM™ Researcher Professional & Indigo Merlin system parts

9

10570103;a3

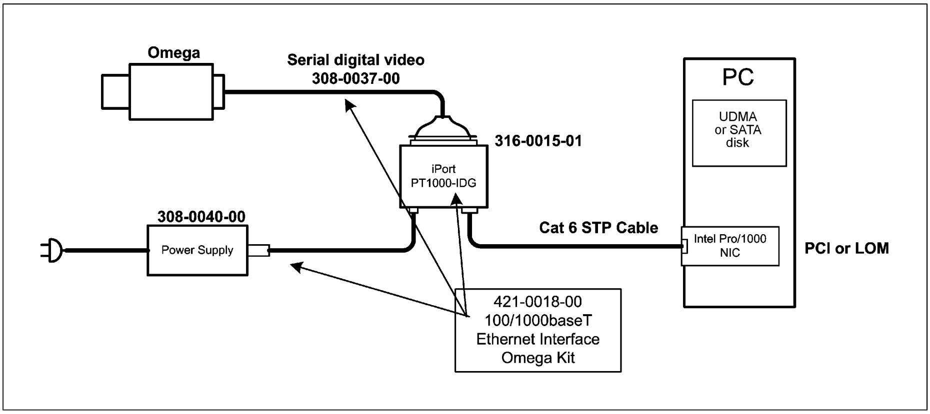

Figure 9.2 ThermaCAM™ Researcher Professional & Indigo Omega system parts

10570203;a4

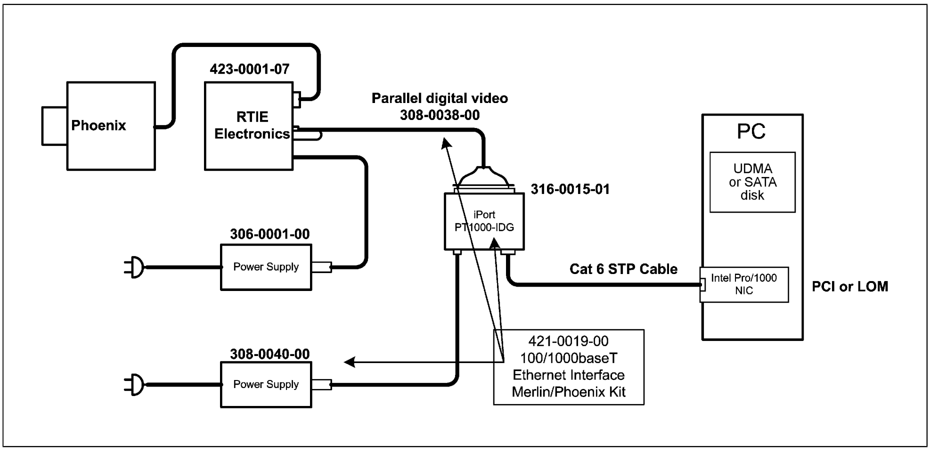

Figure 9.3 ThermaCAM™ Researcher Professional & Indigo Phoenix system parts

10772003;a1

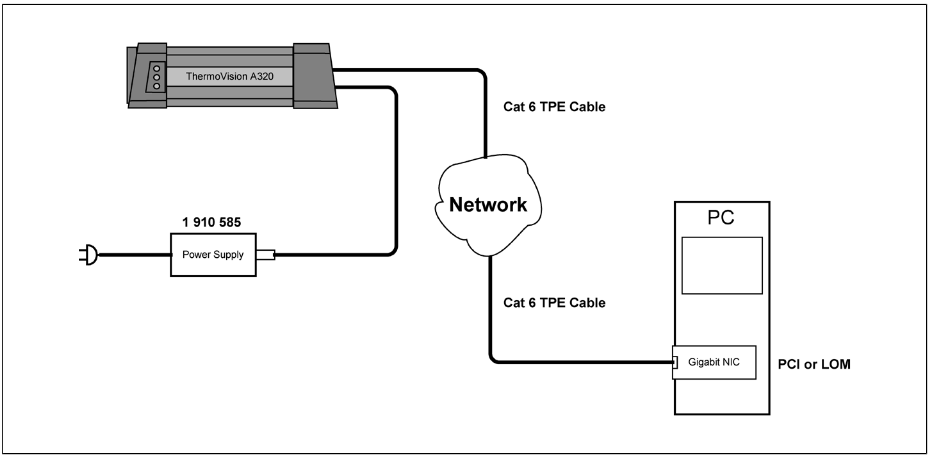

Figure 9.4 ThermaCAM™ Researcher Professional & ThermoVision™ A320G system parts

Necessary parts:

- Intel PRO/1000 compatible Network Interface Card (NIC) in the PC
- An iPort™ PT1000-IDG frame grabber with firmware version 3.8 or later (p/n 316-0015-01)
- A standard CAT6 STP Ethernet cable (up to 100 meters without intervening hardware).
- Cable to connect Merlin with the iPort™ frame grabber (p/n 308-0038-00) or a cable to connect Omega with the iPort™ frame grabber (P/N 308-0037-00)
- ThermaCAM™ Researcher Professional CD-ROM (not shown) including PC driver software.
- A desktop computer with a fast UDMA or SATA disk for high speed image storage

9.2 Software limitations

- The Gigabit Ethernet configuration works on Windows® 2000, Windows® XP, and Windows® Vista (32-bit) operating systems.
- Full burst rate recording of the cameras is only possible when the target disk is formatted with a NT File System (NTFS).
- Pleora and eBus drivers are only supported on Windows® XP and Windows® Vista operating systems.

9.3 PC recommendations

Minimum requirements are:

- A Pentium 4 computer with a clock rate of 1.4 GHz or more.
- At least 512 MB RAM.

- Gigabit Ethernet network adapter (either PCI card or LAN on the motherboard) based on the Intel 82540 network chip (Intel 82541 and Intel 82546 are also acceptable).

To achieve burst recording it should have an 7200 rpm Ultra DMA/100 disk formatted with the NT file system (NTFS). Ultra DMA/100 requires Windows® XP/Vista or service pack 2 of Windows® 2000.

If you have a serial ATA (SATA) disk, that is even better.

9.4 *Installing driver software for the Gigabit Ethernet interface*

9.4.1 Windows® 2000/XP/Vista

To take full advantage of the GigaBit interface you need the eBus optimal driver.

You need to install ThermaCAM™ Researcher Professional before installing this driver.

To copy the eBus driver suite onto your hard disk, run the installation program present in the Pleora eBus folder of the ThermaCAM™ Researcher Professional CD. This will also make some documentation about the driver suite available from the Start Menu. See Pleora Technologies Inc -> eBus Driver suite -> Documentation.

More detailed instructions on how to install the eBus optimal driver can be found in this Pleora documentation.

9

Note that the eBus optimal driver is only compatible with the Intel PRO/1000 family of network adapters (either a PC network interface card, often referred to as a NIC, or a LAN on the motherboard, often referred to as a LOM). If you have some other kind of network adapter, use the universal driver instead.

The ordinary driver for your network adapter has almost certainly already been installed by Windows. You will have to update the previous installation with the Pleora driver.

You need to log in as administrator (or as a user with administrator rights) to do this.

Please follow these steps to replace your Gigabit network interface driver with the Pleora device driver:

1 First make sure that your computer has been fully updated by **Windows® Update**.
2 Run the **Driver Installation Tool** from the **Pleora Technologies, Inc.** -> **eBus Driver suite** menu.
3 Find your Gigabit Ethernet Adapter and select **Configure**.
4 Select the optimal eBus Driver, if you have Intel PRO/1000 adapter, or the universal if you have another adapter. Press **Finish** and, after a while, **Continue**.
5 You may also have to update the new driver.
6 Press Exit and allow the computer to reboot.

If you have Windows® XP Service Pack 2, you will have to let its Firewall allow ThermaCAM™ Researcher Professional to access the network to be able to connect to your camera.

If you do not use an Intel PRO/1000 network adapter or do not install the Pleora drivers, the ThermaCAM™ Researcher Professional software will still allow you to set an IP number to the interface and try to connect to the camera using the ordinary networking functions of Windows. This connection will not give full speed performance for most cameras. For more information about this, please see section 4.3.

If you already had a "High Performance" driver installed for your PT1000 Ethernet adapter, you have to get rid of that by re-installing the original driver from Intel, in order to be able to use the new Driver Installation Tool.

9.4.2 Windows® 95/98/ME/NT 4.0

Not supported.

9.5 Troubleshooting the Gigabit Ethernet interface installation

To work properly, the configuration needs:

- Windows® 2000/XP/Vista (32-bit)
- A functional Network Interface Card (NIC) compatible with the Intel PRO/1000 family of network adapters. Please note that configurations with more than one Gigabit network interface and optimum driver have not been tested.
- An iPort™ PT1000-IDG frame grabber box with firmware version 3.8 (or later), unless it is built into the camera.
- A successful installation of the optimum eBus device driver. You need to install ThermaCAM™ Researcher Professional before installing the device driver.
- A Pentium 4 computer with a clock rate of 1.4 GHz (or faster). At least 512 MB RAM.
- A successful installation of ThermaCAM™ Researcher Professional
- Select **Ethernet** as **Type of connection** in the **Select Camera** dialog.
- NetBIOS enabled on the TCP/IP connection to the camera
- Reliable cables and electrical connections. Gigabit Network adapters require shielded CAT6 cables.
- A camera equipped and configured for digital output.
- Proper settings if you have a firewall in your computer.

SEE ALSO: For more information, see the following documents on the CD:

- Installation Hints (Publ. No. T559004)
- System configurations (Publ. No. 1 557 783)

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10 Standard Ethernet interface configuration

10.1 System parts: Standard Ethernet interface configuration

This configuration is used for the following camera models:

- Merlin uncooled microbolometer
- Merlin NIR (InGaAs)
- Merlin QWIP
- Merlin MID (InSb)
- Omega UL3 uncooled microbolometer
- Phoenix camera with RTIE backend electronics
- ThermoVision™ A320

10574003;a1

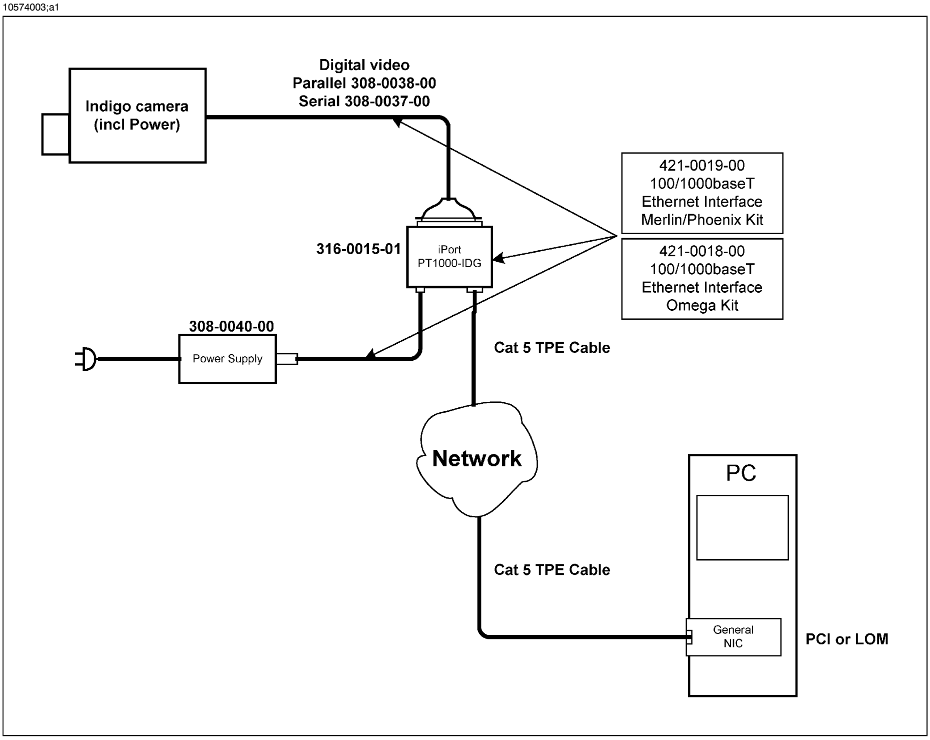

Figure 10.1 ThermaCAM™ Researcher Professional & Indigo Merlin/Omega/Phoenix system parts

10771903;a1

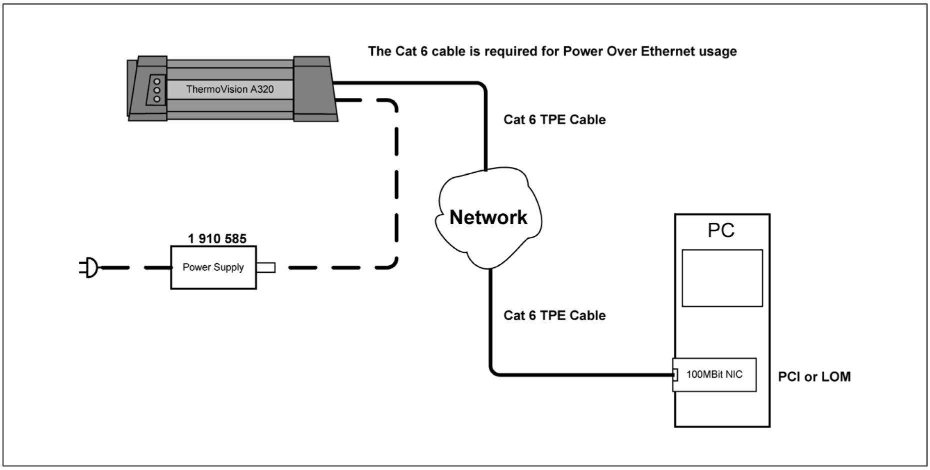

Figure 10.2 ThermaCAM™ Researcher Professional & ThermoVision™ A320 system parts

Necessary parts:

- Any network interface supporting at least Fast Ethernet (100 Mbit/s)
- An iPortTM PT1000-IDG frame grabber with firmware version 3.8 or later
- A standard CAT5 Ethernet cable (up to 100 meters without intervening hardware)
- Cable to connect camera with the iPortTM frame grabber
- ThermaCAM™ Researcher Professional CD-ROM (not shown)
- A desktop or laptop computer

10.2 Software limitations

The Ethernet configuration works on Windows® 2000, Windows® XP, and Windows® Vista (32-bit) operating systems.

Full burst rate recording of the cameras is not possible in this configuration.

10.3 PC recommendations

Minimum requirements are:

- A Pentium 4 computer with a clock rate of 1.4 GHz or more.
- At least 512 MB RAM.
- Any network interface supporting at least Fast Ethernet (100 Mbit/s)

10.4 Ethernet bandwidth requirements

It is important to understand that the cameras in this configuration will stream uncompressed digital video data on the network. This will consume a lot of bandwidth and can affect the normal network traffic causing congestions and slow response.

It is strongly recommended that you configure your network so that the digital video packet data does not affect any normal Ethernet traffic. Small local area networks designated for video streaming is recommended. These networks can either be Fast Ethernet or Gigabit Ethernet networks depending on the camera model (see figure below).

Figure 10.3 Network type recommendations

Camera model	Bandwidth requirement	Network recommendation
Merlin (60 Hz)	~100 Mbit/s	Use Gigabit Ethernet
Omega (30 Hz)	~12 Mbit/s	Use Fast Ethernet
Phoenix (60 Hz) Resolution 320 x 256	~100 Mbit/s	Use Gigabit Ethernet
Phoenix (60 Hz) Resolution 640 x 512	~400 Mbit/s	Use Gigabit Ethernet

10.5 *Troubleshooting the standard Ethernet interface installation*

To work properly, the configuration needs:

- Windows® 2000/XP/Vista (32-bit)
- Any network interface supporting at least Fast Ethernet (100 Mbit/s)
- An iPortTM PT1000-IDG frame grabber with firmware version 3.8 or later
- A Pentium 4 computer with a clock rate of 1.4 GHz or more. At least 512 MB RAM.
- A successful installation of ThermaCAM™ Researcher Professional
- Select **Ethernet** as **Type of connection** in the **Select camera** dialog box
- NetBIOS enabled on the TCP/IP connection to the camera
- Proper settings if you have a firewall in your computer
- Reliable cables and electrical connections
- A camera equipped and configured for digital output
- An IP number assigned to the interface
- An IP number assigned to the camera

SEE ALSO: For more information, see the following documents on the CD:

- Installation Hints (Publ. No. T559004)
- System configurations (Publ. No. 1 557 783)

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11 Disk management

11.1 About Ultra DMA and SATA disks

When the IC2-DIG 16 or IRFlashLink frame grabber, the FireWire interface, or one of the Ethernet interfaces is used to record images at the maximum rate (burst recordings), the speed of the disk I/O is crucial (if you have a PC-Card interface configuration, you can ignore the disk management chapter completely). Until recently, the best solution has been to use SCSI disks and write the images concurrently on two (or more) physical disks that together appear as one single hard disk to the user.

Now, using IDE Ultra DMA/100 (UDMA/100 Ultra or ATA/100) technology, you can take advantage of the latest low-cost, high-performance, high-capacity ATA/IDE hard disks. There are such disks that are so fast that you don't need to use striped volumes.We recommend that you use 7200 RPM 30 GB Ultra DMA/100 disks (or better).

If you have a serial ATA (SATA) disk, that is even better.

Your computer not only has to support this technology, you also have to have service pack 2 of Windows 2000 (or Windows XP/Vista) to make it work. Also, the NTFS file system has to be used when you format the disk.

Some advice:

- Use ATA/100 both for the system disk and the burst disk.
- The burst disk must be strapped as an IDE slave disk.
- Connect i to the same IDE bus as the system disk and check that no tother equipment is connected to this cable.
- Check the IDE ATA controller settings of the **Device Manager**. The primary channel transfer mode has to be **DMA if available** and the current transfer mode has to be **Ultra DMA Mode**. Some BIOS settings can affect the transfer mode too.

11

11.2 Creating stripe sets and formatting NTFS disks in Windows

- This applies to Windows NT 4/2000/XP only
- You must have Administrator privileges to carry out disk management work
- A stripe set (in Windows 2000/XP called striped volume) makes two or more physical disks appear as one single hard disk to the user

11.2.1 Windows NT 4.0 stripe sets

NOTE: Information about a stripe set is kept in binary format in the Registry of your computer. You cannot move the Windows NT 4.0 striped disks to any another computer and retain the data without moving this information as well.

11.2.1.1 Partition the burst disks in Windows NT 4.0

Step	Action
1	Click on **Start** → **Programs** → **Administrative Tools** → **Disk Administrator**. If Windows NT 4.0 asks if you want a disk signature, click on the **Yes** button.
2	When the disk administrator has started, click on **SCSI Disk 1**, press the CTRL button and click on **SCSI Disk 2**. This will mark both disk 1 and disk 2. **NOTE:** Make sure that no other disks are marked.
3	Open the **Partition** menu and select **Create Stripe Set**.
4	On the **Create Stripe Set** dialog box, click on the **OK** button.
5	Open the menu again and select **Commit Changes Now**. On the **Confirm** dialog box, click on the **Yes** button and click **Yes** again when asked to restart the computer.

11.2.1.2 Format the burst disks in Windows NT 4.0

Step	Action
1	Start the **Disk Administrator** again and click on **SCSI disk 1** (both disk 1 and disk 2 should now be highlighted).
2	Open the **Tools** menu, select **Format**. On the dialog box change the **File System** selection to **NTFS**, mark **Quick Format** and click on the **Start** button.
3	On the **Format** dialog box, click on the **OK** button.
4	When the disks are formatted, select **Close**. Leave the **Disk Administrator**.

11.2.2 Windows 2000/XP striped volumes

NOTE: In Windows 2000 and XP, striped volumes can be moved to another computer.

11

11.2.2.1 Creating and formatting striped volumes in Windows 2000/XP

Step	Action
1	Click on **Start** → **Settings** → **Control Panel**. Double-click on the **Administrative Tools** and **Computer Management** icons.
2	When the **Computer Management** window has started, click on **Storage** and **Disk Management** in the left view. The two SCSI disks will now appear as basic disks, each one with a separate drive letter and a separate number, normally **Disk 1** and **Disk 2.** If other numbers appear, use them instead in the description below.
3	Click with the right mouse button on the text **Basic** below the text **Disk 1**. Select **Upgrade** to dynamic disk from the menu. Mark the proper two SCSI disks in the dialog box that appears. Click **OK.**

Step	Action
4	From the same menu for **Disk 1**, select **Create Volume**. If the entry isn't active, you may have to select **Delete Volume** first.
5	Click **Next** to skip the **Welcome** dialog box. In the next dialog box that appears, select **Striped Volume** as the volume type. Click **Next**.
6	Select the other SCSI disk and click **Add**. Click **Next**.
7	Assign a drive letter to the striped volume. Click **Next**.
8	Select the NTFS file system for the new volume. Click **Next**.
9	Check that the information on the last dialog box is correct. Click **Finish**. The formatting of the new volume will now begin.

11.2.2.2 Importing striped volumes in Windows 2000/XP

Step	Action
1	To import a volume, striped on one Windows 2000/XP computer into another Windows 2000/XP computer, click on **Start** → **Settings** → **Control Panel**.
2	Double-click on the **Administrative Tools** and **Computer Management icons**.
3	When the **Computer Management** window has started, click on **Storage** and **Disk Management** in the left view. The two SCSI disks will now appear as foreign disks, each one with a separate number, normally **Disk 1** and **Disk 2**. If other numbers appear, use them instead.
4	Click with the right mouse button on the text **Foreign** below the text **Disk 1**. Select **Import foreign disks** from the menu. Mark the right two SCSI disks in the dialog box that appears. Click **OK.**
5	On the next dialog box, select an appropriate drive letter and click **OK**.

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12 OLE tricks & tips

12.1 *OLE in brief*

12.1.1 Copying information to other applications

If you want to copy information in ThermaCAM™ Researcher Professional to another application you must first copy the data and put it on the clipboard. There are two commands on the **Edit** menu you can use: **Copy session and image** which will copy the session and the entire IR image and **Copy value** which will load a dialog box where you can select the information you want to be copied.

You can also copy data from the result table, from the histogram window, from the profile window and from the plot window to the clipboard. Right-click in the corresponding window and select **Copy**.

To control how information is pasted, use the **Paste Special** command on the **Edit** menu in the receiving application.

12.1.2 Linking into other applications

Creating a link:

- Start ThermaCAM™ Researcher Professional as a standalone application.
- Save the session as an .irs file.
- On the **Edit** menu, click **Copy session and image** to copy the IR image to the clipboard.
- Alternatively, click **Copy value** and select the value to copy.
- In the other application, click where you want the linked ThermaCAM™ Researcher Professional image to be placed.
- On the **Edit** menu, click **Paste Special**.
- To paste as a link, select the **Paste Link** option and **Picture Object**.
- Click **OK**.

12.1.3 Embedding into other applications

Creating an embedded object:

- Start the application in which you want to embed ThermaCAM™ Researcher Professional.
- Click where you want to embed ThermaCAM™ Researcher Professional.
- Open the dialog box where you insert objects. It depends on the application how this dialog box is loaded. In Microsoft® Excel and Microsoft® Word you click **Object** in the **Insert** menu.
- In the **Object Type** box, click **ThermaCAM™ Researcher Professional Session**.
- Click **OK**.

Editing an embedded object:

Double-click the **ThermaCAM™ Researcher Professional Session** object to open it for editing. The menus and toolbars in the application are replaced so that you can edit the embedded object in place.

12.1.4 Automation

By using OLE Automation, it is possible to manipulate ThermaCAM™ Researcher Professional from the outside. You can instruct ThermaCAM™ Researcher Professional to load images, query it about temperatures etc.

This interface is available from many programming languages such as Visual Basic for applications VBA (used in Microsoft® Excel), VB script (available in Windows 98, Me and 2000) and "ordinary" Visual Basic.

Some examples can be found in the Microsoft® Excel samples that are installed in the **Example** directory (a subdirectory to that ThermaCAM™ Researcher Professional installation directory).

A full Visual Basic project is included in the **VBDemo** directory of the CD-ROM.

There are many books on the market that describe VBA and how to use it in e.g. Microsoft® Excel.

SEE ALSO: For more information about OLE, see the following document on the CD:

- OLE Automation (Publ. No. T559011)

12.2 OLE caveats

If ThermaCAM™ Researcher Professional is embedded or linked to the Microsoft® Office programs, e.g., Microsoft® Word or Microsoft® Excel there might be some strange behaviours you didn't expect. The main reason for this is that the Microsoft® Office programs handle OLE in different ways and ThermaCAM™ Researcher Professional cannot work perfectly in all environments. This chapter describes some of the peculiarities and ways to work around them.

12

12.2.1 Colors

Problem	Solution
In some applications, e.g. Microsoft® Word, the image can be drawn using the wrong colors. Instead of using the colors in the selected palette (e.g. **Rainbow**) the image is drawn in randomly selected colors.	Change the settings for your video card so it uses more than 256 colors. Depending on your video card, use 32000, 64000 or Truecolor. Refer to the documentation of your video card. **NOTE:** This may affect the performance of the live image presentation.

12.2.2 Incorrect aspect ratio

Problem	Solution
When you change the size of the IR image it can get incorrect proportions, i.e. it becomes elongated either horizontally or vertically.	You have to avoid doing this. Different programs provide different means of resizing an embedded object with out changing the aspect ratio. In some cases you should catch the corners, in other cases you should press the SHIFT key while resizing the object.

12.2.3 Multiple links do not update in Microsoft® Word

Problem	Solution
If you have more than one link from the same IR image (e.g. one link from the IR image and one link for a spot meter temperature) it might happen that only one of links will be updated when you modify the IR image.	The problem is that when the links shall be updated Microsoft® Word cannot handle more than one link. The easiest solution to this problem is to select all text in Microsoft® Word (press CTRL + A) and then press F9 to update the entire document.

12.2.4 Microsoft® Word consumes lots of disk space for live images

Problem	Solution
If you embed ThermaCAM™ Researcher Professional in Microsoft® Word and try to present a live image, Microsoft® Word will get busy slowly filling your hard disk. Sometimes, it proves impossible to do anything but restarting the computer.	Live image presentation in Microsoft® Word should be avoided. The lost disk space is recovered when the computer is restarted.

12.2.5 Microsoft® Excel does not accept our numerical values

<table>
<tr><th>Problem</th><th>Solution</th></tr>
<tr><td>Under some circumstances, the Microsoft® Excel cells will refuse to accept numeric values from ThermaCAM™ Researcher Professional. This is due to the fact that ThermaCAM™ Researcher Professional will “decorate” the values with <, > and * signs, if the temperatures are out of range.</td><td>We recommend that you select a better measurement range in this case. If that proves impossible, there is a possibility for you to switch off these decorations altogether. Then, in the registry of your computer, set the following parameter to 0 instead of 1 and restart ThermaCAM™ Researcher Professional.
<pre>
My computer\
   HKEY_CURRENT_USER\
      Software\
         FLIR Systems AB\
           ThermaCAM™ Researcher Profession-
al XXXX\
                Settings\
                   IllegalTempIndicator = 0
</pre></td></tr>
</table>

12

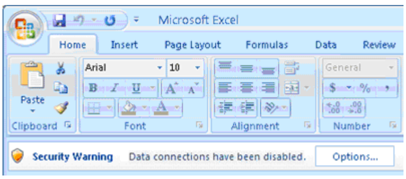
12.2.6 Security warnings with Microsoft® Excel 2007 files

Before Microsoft® Office 2007, when you opened an .xls file with embeddings or links, Excel politely asked whether or not the content of the sheet should be updated. This has now become much more complicated.

Microsoft® Office 2007 has new feature called Trust Center. The security levels that were used in earlier versions of Office are now replaced with a more streamlined security system.

When you open a file with links or embeddings, Excel will display a security warning:

10771703;a1



If you click on the options button, a dialog is displayed allowing you to enable the connections.

Excel 2007 will start ThermaCAM™ Researcher Professional in advance, even before you double-click on the embedding. This can cause problems when you connect to the camera.

When you double-click on the ThermaCAM™ Researcher Professional embedding, its links will still not automatically go live. Choose **Data**/**Edit links** from the Excel menu. In the **Edit links** dialog, press Ctrl-A to select all the links of the sheet and click on **Update Values**. Close the dialog.

If you want to open a workbook that contains a data connection without receiving security warnings, you have to change the settings of the **Trust Center**. To find it, click the  button and select **Excel options** and **Trust Center**.

In the **Trust Center External Content** tab, there is a **Security Setting for Workbook Links** that you can enable if you like. Microsoft® does not recommend this.

Another way to open a workbook that contains a data connection without receiving security warnings is to put the file in a **Trusted Location** listed on the **Trusted Locations** tab of the **Trust Center**. Microsoft does not recommend adding the whole of My Documents to this list.

13 Thermographic measurement techniques

13.1 Introduction

An infrared camera measures and images the emitted infrared radiation from an object. The fact that radiation is a function of object surface temperature makes it possible for the camera to calculate and display this temperature.

However, the radiation measured by the camera does not only depend on the temperature of the object but is also a function of the emissivity. Radiation also originates from the surroundings and is reflected in the object. The radiation from the object and the reflected radiation will also be influenced by the absorption of the atmosphere.

To measure temperature accurately, it is therefore necessary to compensate for the effects of a number of different radiation sources. This is done on-line automatically by the camera. The following object parameters must, however, be supplied for the camera:

- The emissivity of the object
- The reflected temperature
- The distance between the object and the camera
- The relative humidity

13.2 Emissivity

The most important object parameter to set correctly is the emissivity which, in short, is a measure of how much radiation is emitted from the object, compared to that from a perfect blackbody of the same temperature.

Normally, object materials and surface treatments exhibit emissivity ranging from approximately 0.1 to 0.95. A highly polished (mirror) surface falls below 0.1, while an oxidized or painted surface has a higher emissivity. Oil-based paint, regardless of color in the visible spectrum, has an emissivity over 0.9 in the infrared. Human skin exhibits an emissivity 0.97 to 0.98.

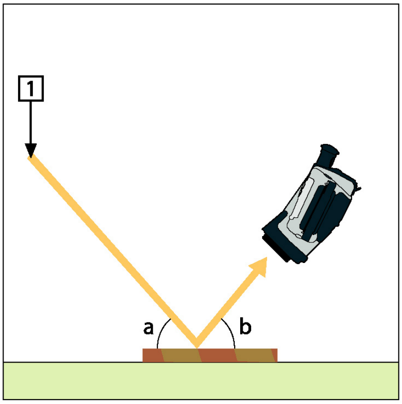
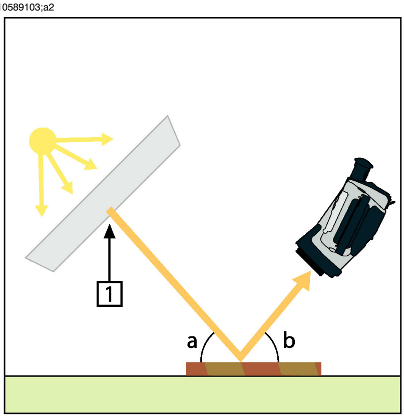
Non-oxidized metals represent an extreme case of perfect opacity and high reflexivity, which does not vary greatly with wavelength. Consequently, the emissivity of metals is low – only increasing with temperature. For non-metals, emissivity tends to be high, and decreases with temperature.

13.2.1 Finding the emissivity of a sample

13.2.1.1 Step 1: Determining reflected apparent temperature

Use one of the following two methods to determine reflected apparent temperature:

13.2.1.1.1 Method 1: Direct method

1	Look for possible reflection sources, considering that the incident angle = reflection angle (a = b). 10588903;a1  **Figure 13.1** 1 = Reflection source
2	If the reflection source is a spot source, modify the source by obstructing it using a piece if cardboard. 10589103;a2  **Figure 13.2** 1 = Reflection source

<table>
<tr><td>3</td><td>Measure the radiation intensity (= apparent temperature) from the reflecting source using the following settings:

Emissivity: 1.0
D_{obj}: 0

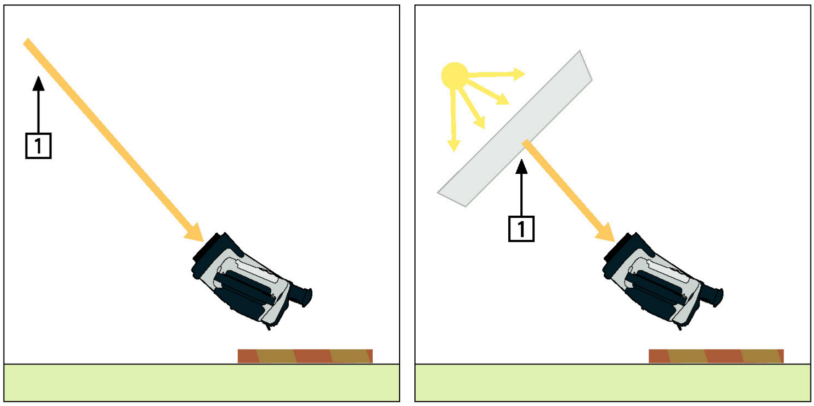
You can measure the radiation intensity using one of the following two methods:
10589003;a2


Figure 13.3 1 = Reflection source</td></tr>
</table>

Note: Using a thermocouple to measure reflected apparent temperature is not recommended for two important reasons:

- A thermocouple does not measure radiation intensity
- A thermocouple requires a very good thermal contact to the surface, usually by gluing and covering the sensor by a thermal isolator.

13.2.1.1.2 Method 2: Reflector method

1	Crumble up a large piece of aluminum foil.
2	Uncrumble the aluminum foil and attach it to a piece of cardboard of the same size.
3	Put the piece of cardboard in front of the object you want to measure. Make sure that the side with aluminum foil points to the camera.
4	Set the emissivity to 1.0.

5	Measure the apparent temperature of the aluminum foil and write it down.

10727003;a2

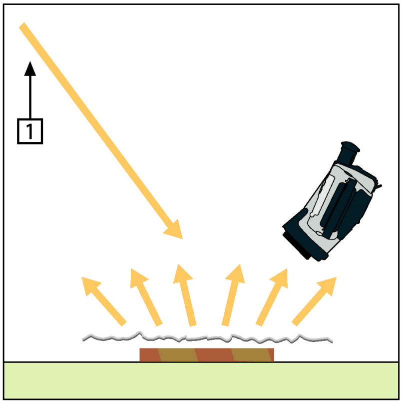


Figure 13.4 Measuring the apparent temperature of the aluminum foil

13.2.1.2 Step 2: Determining the emissivity

1	Select a place to put the sample.
2	Determine and set reflected apparent temperature according to the previous procedure.
3	Put a piece of electrical tape with known high emissivity on the sample.
4	Heat the sample at least 20 K above room temperature. Heating must be reasonably even.
5	Focus and auto-adjust the camera, and freeze the image.
6	Adjust **Level** and **Span** for best image brightness and contrast.
7	Set emissivity to that of the tape (usually 0.97).
8	Measure the temperature of the tape using one of the following measurement functions: ▪ **Isotherm** (helps you to determine both the temperature and how evenly you have heated the sample) ▪ **Spot** (simpler) ▪ **Box Avg** (good for surfaces with varying emissivity).
9	Write down the temperature.
10	Move your measurement function to the sample surface.
11	Change the emissivity setting until you read the same temperature as your previous measurement.
12	Write down the emissivity.

Note:

- Avoid forced convection
- Look for a thermally stable surrounding that will not generate spot reflections
- Use high quality tape that you know is not transparent, and has a high emissivity you are certain of
- This method assumes that the temperature of your tape and the sample surface are the same. If they are not, your emissivity measurement will be wrong.

13.3 Distance

The distance is the distance between the object and the front lens of the camera.

This parameter is used to compensate for the fact that radiation is being absorbed between the object and the camera and the fact that transmittance drops with distance.

13.4 Reflected temperature

This parameter is used to compensate for the radiation reflected in the object.

In some cameras, it is also called *background temperature.*

If the emissivity is low and the object temperature relatively close to that of the ambient it will be very important to set and compensate for the reflected temperature correctly.

13.5 Atmospheric temperature, humidity and distance

These parameters are used to correct for the fact that radiation is being absorbed in the atmosphere between the object and the camera and the fact that transmittance drops with distance.

If the humidity of the air is high, the distance very long and the object temperature relatively close to that of the atmosphere it will be important to set and compensate for the atmosphere correctly.

The distance is the distance between the object and the front lens of the camera.

The transmittance is heavily dependent on the relative humidity of the air. To compensate for this, set the relative humidity to the correct value. For short distances of air with normal humidity, the relative humidity can usually be left at a default value of 50 %.

If you have a better estimate of the properties of the atmosphere than the built-in model has, you can enter your estimated transmission value instead.

To avoid applying this type of compensation, please set the estimated transmission to 1.0.

13.6 External optics transmission and temperature

Sometimes, the radiation from the object also has to pass through some optical accessory, such as a heat shield or a macro lens, before reaching the camera. Then that optics, external to the camera, will absorb some of the radiation. To correct for this effect, enter the transmittance and temperature of the optics.

Ambient reflections in the external optics are not taken into consideration mathematically, so the optics either has to have a non-reflective coating or have the same temperature as the ambient (on the camera side) to make the correction work properly.

Please avoid ambient reflections. Do, for instance, make sure that the camera cannot see itself mirrored in the external optics.

To avoid applying this type of compensation, please set the external optics transmission to 1.0.

13.7 Infrared spectral filters

Any object, with a temperature above 0 Kelvin, will emit electromagnetic radiation over a wide spectrum. The hotter the object, the stronger and wider the radiation, and the shorter its wavelength. Infrared detectors are only sensitive in parts of the infrared waveband. This means that the temperature calculations in infrared cameras make assumptions about the amount of radiation present in other wavebands.

Infrared cameras are calibrated with a set of standard blackbodies at various temperatures. Any object in air, behaving like a blackbody, can thus be treated properly by the camera. Sometimes, there are different conditions. Hot gases, for instance, emit radiation only at discrete wavelengths, “stripes”. Cold gases absorb radiation in stripes. To be able to make accurate measurements under such circumstances, you have to use the right spectral filters.

13.8 Units of measure

Thermography really means making images of thermal surface property variations of objects. The most natural property to measure is of course temperature, which has the units Celsius, Fahrenheit and Kelvin in ThermaCAM™ Researcher Professional.

Another interesting property is the total amount of radiation emitted from the object but, since the infrared camera is sensitive only to parts of the spectrum, no accurate such measurement can be made. Hence no standardised unit is available for radiation display. Instead, the non-calibrated unit *object signal* (abbreviated OS) has been invented. Being approximately proportional to the amount of radiation sensed by the

camera detector, it can be used for comparative radiation measurements within the same measurement range for the same camera. If you intend to use it in some other way, you have to provide a calibration of your own.

Some measurements, such as the standard deviation, produce a result which best could be described as a *difference temperature* (or *difference object signal*). They involve a subtraction, which cancels out the existing absolute level. A standard deviation of 2.5 at 25 °C is the same thing as a standard deviation of 2.5 at 50 °C. In such cases, the units DeltaCelsius (dC), DeltaFahrenheit (dF), DeltaKelvin (dK) and DeltaObjectSignal (dOS) apply.

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14 About FLIR Systems

FLIR Systems was established in 1978 to pioneer the development of high-performance infrared imaging systems, and is the world leader in the design, manufacture, and marketing of thermal imaging systems for a wide variety of commercial, industrial, and government applications. Today, FLIR Systems embraces four major companies with outstanding achievements in infrared technology since 1965—the Swedish AGEMA Infrared Systems (formerly AGA Infrared Systems), and the three United States companies Indigo Systems, FSI, and Inframetrics.

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Figure 14.1 LEFT: Thermovision® Model 661 from 1969. The camera weighed approximately 25 kg (55 lb.), the oscilloscope 20 kg (44 lb.), and the tripod 15 kg (33 lb.). The operator also needed a 220 VAC generator set, and a 10 L (2.6 US gallon) jar with liquid nitrogen. To the left of the oscilloscope the Polaroid attachment (6 kg/13 lb.) can be seen. **RIGHT:** FLIR i5 from 2008. Weight: 0.34 kg (0.75 lb.), including the battery.

The company has sold more than 40,000 infrared cameras worldwide for applications such as predictive maintenance, R & D, non-destructive testing, process control and automation, and machine vision, among many others.

FLIR Systems has three manufacturing plants in the United States (Portland, OR, Boston, MA, Santa Barbara, CA) and one in Sweden (Stockholm). Direct sales offices in Belgium, Brazil, China, France, Germany, Great Britain, Hong Kong, Italy, Japan, Sweden, and the USA—together with a worldwide network of agents and distributors—support our international customer base.

FLIR Systems is at the forefront of innovation in the infrared camera industry. We anticipate market demand by constantly improving our existing cameras and developing new ones. The company has set milestones in product design and development such as the introduction of the first battery-operated portable camera for industrial inspections, and the first uncooled infrared camera, to mention just two innovations.

FLIR Systems manufactures all vital mechanical and electronic components of the camera systems itself. From detector design and manufacturing, to lenses and system electronics, to final testing and calibration, all production steps are carried out and supervised by our own engineers. The in-depth expertise of these infrared specialists ensures the accuracy and reliability of all vital components that are assembled into your infrared camera.

14.1 More than just an infrared camera

At FLIR Systems we recognize that our job is to go beyond just producing the best infrared camera systems. We are committed to enabling all users of our infrared camera systems to work more productively by providing them with the most powerful camera–software combination. Especially tailored software for predictive maintenance, R & D, and process monitoring is developed in-house. Most software is available in a wide variety of languages.

We support all our infrared cameras with a wide variety of accessories to adapt your equipment to the most demanding infrared applications.

14.2 Sharing our knowledge

Although our cameras are designed to be very user-friendly, there is a lot more to thermography than just knowing how to handle a camera. Therefore, FLIR Systems has founded the Infrared Training Center (ITC), a separate business unit, that provides certified training courses. Attending one of the ITC courses will give you a truly hands-on learning experience.

The staff of the ITC are also there to provide you with any application support you may need in putting infrared theory into practice.

14.3 Supporting our customers

FLIR Systems operates a worldwide service network to keep your camera running at all times. If you discover a problem with your camera, local service centers have all the equipment and expertise to solve it within the shortest possible time. Therefore, there is no need to send your camera to the other side of the world or to talk to someone who does not speak your language.

14.4 A few images from our facilities

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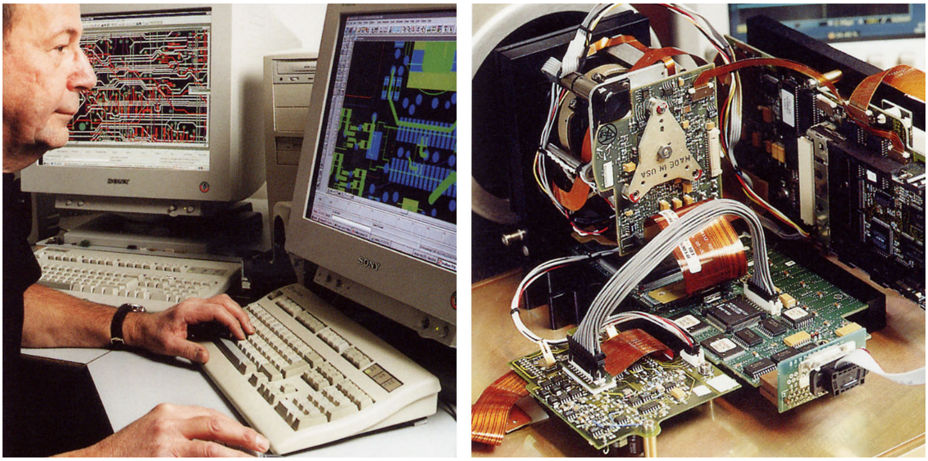

Figure 14.2 LEFT: Development of system electronics; **RIGHT:** Testing of an FPA detector

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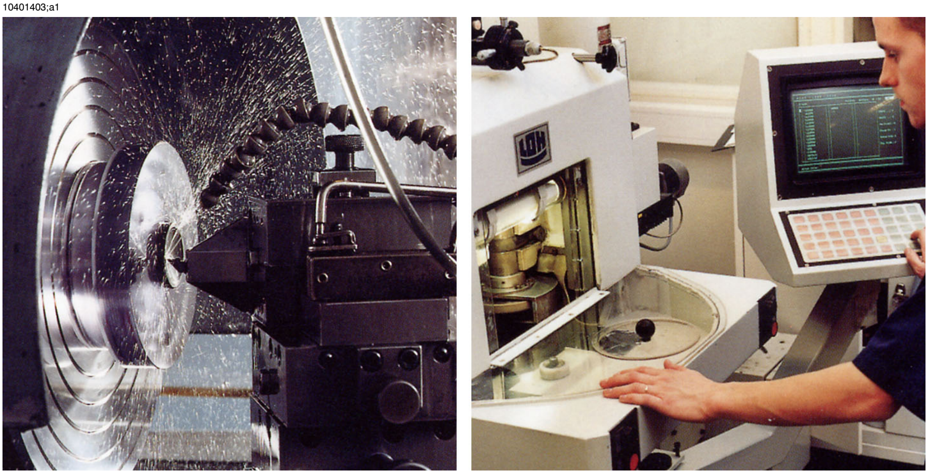

Figure 14.3 LEFT: Diamond turning machine; **RIGHT:** Lens polishing

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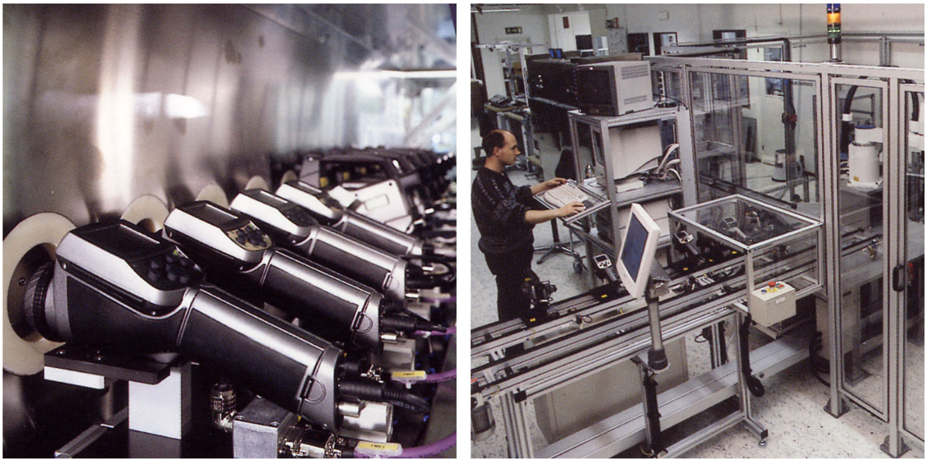

Figure 14.4 LEFT: Testing of infrared cameras in the climatic chamber; **RIGHT:** Robot used for camera testing and calibration

15 History of infrared technology

Before the year 1800, the existence of the infrared portion of the electromagnetic spectrum wasn't even suspected. The original significance of the infrared spectrum, or simply 'the infrared' as it is often called, as a form of heat radiation is perhaps less obvious today than it was at the time of its discovery by Herschel in 1800.

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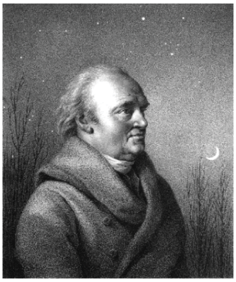

Figure 15.1 Sir William Herschel (1738–1822)

The discovery was made accidentally during the search for a new optical material. Sir William Herschel – Royal Astronomer to King George III of England, and already famous for his discovery of the planet Uranus – was searching for an optical filter material to reduce the brightness of the sun's image in telescopes during solar observations. While testing different samples of colored glass which gave similar reductions in brightness he was intrigued to find that some of the samples passed very little of the sun's heat, while others passed so much heat that he risked eye damage after only a few seconds' observation.

Herschel was soon convinced of the necessity of setting up a systematic experiment, with the objective of finding a single material that would give the desired reduction in brightness as well as the maximum reduction in heat. He began the experiment by actually repeating Newton's prism experiment, but looking for the heating effect rather than the visual distribution of intensity in the spectrum. He first blackened the bulb of a sensitive mercury-in-glass thermometer with ink, and with this as his radiation detector he proceeded to test the heating effect of the various colors of the spectrum formed on the top of a table by passing sunlight through a glass prism. Other thermometers, placed outside the sun's rays, served as controls.

As the blackened thermometer was moved slowly along the colors of the spectrum, the temperature readings showed a steady increase from the violet end to the red end. This was not entirely unexpected, since the Italian researcher, Landriani, in a similar experiment in 1777 had observed much the same effect. It was Herschel,

however, who was the first to recognize that there must be a point where the heating effect reaches a maximum, and that measurements confined to the visible portion of the spectrum failed to locate this point.

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Figure 15.2 Marsilio Landriani (1746–1815)

Moving the thermometer into the dark region beyond the red end of the spectrum, Herschel confirmed that the heating continued to increase. The maximum point, when he found it, lay well beyond the red end – in what is known today as the 'infrared wavelengths'.

When Herschel revealed his discovery, he referred to this new portion of the electromagnetic spectrum as the 'thermometrical spectrum'. The radiation itself he sometimes referred to as 'dark heat', or simply 'the invisible rays'. Ironically, and contrary to popular opinion, it wasn't Herschel who originated the term 'infrared'. The word only began to appear in print around 75 years later, and it is still unclear who should receive credit as the originator.

Herschel's use of glass in the prism of his original experiment led to some early controversies with his contemporaries about the actual existence of the infrared wavelengths. Different investigators, in attempting to confirm his work, used various types of glass indiscriminately, having different transparencies in the infrared. Through his later experiments, Herschel was aware of the limited transparency of glass to the newly-discovered thermal radiation, and he was forced to conclude that optics for the infrared would probably be doomed to the use of reflective elements exclusively (i.e. plane and curved mirrors). Fortunately, this proved to be true only until 1830, when the Italian investigator, Melloni, made his great discovery that naturally occurring rock salt (NaCl) – which was available in large enough natural crystals to be made into lenses and prisms – is remarkably transparent to the infrared. The result was that rock salt became the principal infrared optical material, and remained so for the next hundred years, until the art of synthetic crystal growing was mastered in the 1930's.

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Figure 15.3 Macedonio Melloni (1798–1854)

Thermometers, as radiation detectors, remained unchallenged until 1829, the year Nobili invented the thermocouple. (Herschel's own thermometer could be read to 0.2 °C (0.036 °F), and later models were able to be read to 0.05 °C (0.09 °F)). Then a breakthrough occurred; Melloni connected a number of thermocouples in series to form the first thermopile. The new device was at least 40 times as sensitive as the best thermometer of the day for detecting heat radiation – capable of detecting the heat from a person standing three meters away.

The first so-called 'heat-picture' became possible in 1840, the result of work by Sir John Herschel, son of the discoverer of the infrared and a famous astronomer in his own right. Based upon the differential evaporation of a thin film of oil when exposed to a heat pattern focused upon it, the thermal image could be seen by reflected light where the interference effects of the oil film made the image visible to the eye. Sir John also managed to obtain a primitive record of the thermal image on paper, which he called a 'thermograph'.

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Figure 15.4 Samuel P. Langley (1834–1906)

The improvement of infrared-detector sensitivity progressed slowly. Another major breakthrough, made by Langley in 1880, was the invention of the bolometer. This consisted of a thin blackened strip of platinum connected in one arm of a Wheatstone bridge circuit upon which the infrared radiation was focused and to which a sensitive galvanometer responded. This instrument is said to have been able to detect the heat from a cow at a distance of 400 meters.

An English scientist, Sir James Dewar, first introduced the use of liquefied gases as cooling agents (such as liquid nitrogen with a temperature of -196 °C (-320.8 °F)) in low temperature research. In 1892 he invented a unique vacuum insulating container in which it is possible to store liquefied gases for entire days. The common 'thermos bottle', used for storing hot and cold drinks, is based upon his invention.

Between the years 1900 and 1920, the inventors of the world 'discovered' the infrared. Many patents were issued for devices to detect personnel, artillery, aircraft, ships – and even icebergs. The first operating systems, in the modern sense, began to be developed during the 1914–18 war, when both sides had research programs devoted to the military exploitation of the infrared. These programs included experimental systems for enemy intrusion/detection, remote temperature sensing, secure communications, and 'flying torpedo' guidance. An infrared search system tested during this period was able to detect an approaching airplane at a distance of 1.5 km (0.94 miles), or a person more than 300 meters (984 ft.) away.

The most sensitive systems up to this time were all based upon variations of the bolometer idea, but the period between the two wars saw the development of two revolutionary new infrared detectors: the image converter and the photon detector. At first, the image converter received the greatest attention by the military, because it enabled an observer for the first time in history to literally 'see in the dark'. However, the sensitivity of the image converter was limited to the near infrared wavelengths, and the most interesting military targets (i.e. enemy soldiers) had to be illuminated by infrared search beams. Since this involved the risk of giving away the observer's position to a similarly-equipped enemy observer, it is understandable that military interest in the image converter eventually faded.

The tactical military disadvantages of so-called 'active' (i.e. search beam-equipped) thermal imaging systems provided impetus following the 1939–45 war for extensive secret military infrared-research programs into the possibilities of developing 'passive' (no search beam) systems around the extremely sensitive photon detector. During this period, military secrecy regulations completely prevented disclosure of the status of infrared-imaging technology. This secrecy only began to be lifted in the middle of the 1950's, and from that time adequate thermal-imaging devices finally began to be available to civilian science and industry.

16 Theory of thermography

16.1 Introduction

The subjects of infrared radiation and the related technique of thermography are still new to many who will use an infrared camera. In this section the theory behind thermography will be given.

16.2 The electromagnetic spectrum

The electromagnetic spectrum is divided arbitrarily into a number of wavelength regions, called *bands*, distinguished by the methods used to produce and detect the radiation. There is no fundamental difference between radiation in the different bands of the electromagnetic spectrum. They are all governed by the same laws and the only differences are those due to differences in wavelength.

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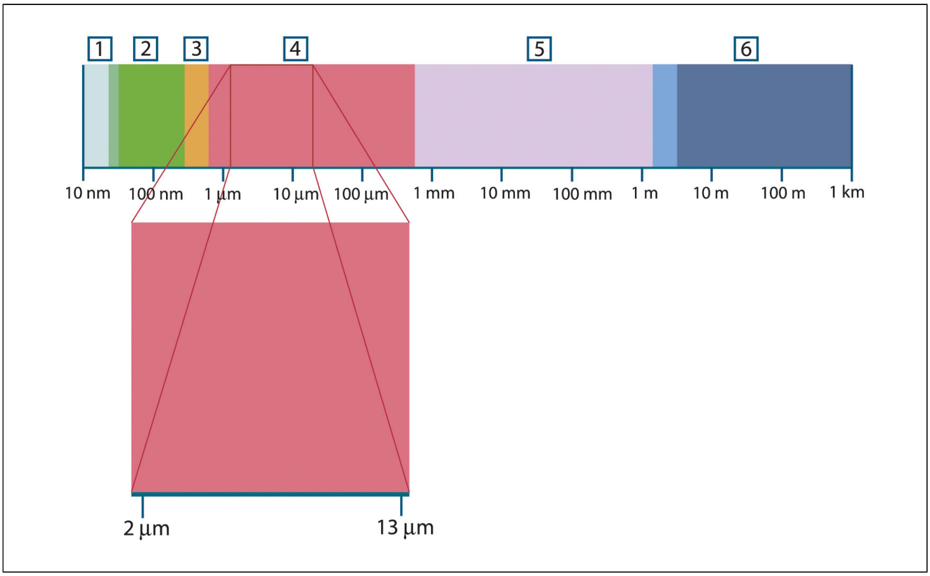

Figure 16.1 The electromagnetic spectrum. **1:** X-ray; **2:** UV; **3:** Visible; **4:** IR; **5:** Microwaves; **6:** Radiowaves.

Thermography makes use of the infrared spectral band. At the short-wavelength end the boundary lies at the limit of visual perception, in the deep red. At the long-wavelength end it merges with the microwave radio wavelengths, in the millimeter range.

The infrared band is often further subdivided into four smaller bands, the boundaries of which are also arbitrarily chosen. They include: the *near infrared* (0.75–3 µm), the *middle infrared* (3–6 µm), the *far infrared* (6–15 µm) and the *extreme infrared* (15–100

µm). Although the wavelengths are given in µm (micrometers), other units are often still used to measure wavelength in this spectral region, *e.g.* nanometer (nm) and Ångström (Å).

The relationships between the different wavelength measurements is:

$$10\ 000\ \text{Å} = 1\ 000\ \text{nm} = 1\ \mu = 1\ \mu\text{m}$$

16.3 Blackbody radiation

A blackbody is defined as an object which absorbs all radiation that impinges on it at any wavelength. The apparent misnomer *black* relating to an object emitting radiation is explained by Kirchhoff's Law (after *Gustav Robert Kirchhoff*, 1824–1887), which states that a body capable of absorbing all radiation at any wavelength is equally capable in the emission of radiation.

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Figure 16.2 Gustav Robert Kirchhoff (1824–1887)

The construction of a blackbody source is, in principle, very simple. The radiation characteristics of an aperture in an isotherm cavity made of an opaque absorbing material represents almost exactly the properties of a blackbody. A practical application of the principle to the construction of a perfect absorber of radiation consists of a box that is light tight except for an aperture in one of the sides. Any radiation which then enters the hole is scattered and absorbed by repeated reflections so only an infinitesimal fraction can possibly escape. The blackness which is obtained at the aperture is nearly equal to a blackbody and almost perfect for all wavelengths.

By providing such an isothermal cavity with a suitable heater it becomes what is termed a *cavity radiator*. An isothermal cavity heated to a uniform temperature generates blackbody radiation, the characteristics of which are determined solely by the temperature of the cavity. Such cavity radiators are commonly used as sources of radiation in temperature reference standards in the laboratory for calibrating thermographic instruments, such as a FLIR Systems camera for example.

If the temperature of blackbody radiation increases to more than 525°C (977°F), the source begins to be visible so that it appears to the eye no longer black. This is the incipient red heat temperature of the radiator, which then becomes orange or yellow as the temperature increases further. In fact, the definition of the so-called *color temperature* of an object is the temperature to which a blackbody would have to be heated to have the same appearance.

Now consider three expressions that describe the radiation emitted from a blackbody.

16.3.1 Planck's law

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Figure 16.3 Max Planck (1858–1947)

Max Planck (1858–1947) was able to describe the spectral distribution of the radiation from a blackbody by means of the following formula:

$$W_{\lambda b} = \frac{2\pi hc^2}{\lambda^5 \left(e^{hc/\lambda kT} - 1\right)} \times 10^{-6} [Watt/m^2, \mu m]$$

where:

$W_{\lambda b}$	Blackbody spectral radiant emittance at wavelength λ.
c	Velocity of light = 3 × 10^8 m/s
h	Planck's constant = 6.6 × 10^{-34} Joule sec.
k	Boltzmann's constant = 1.4 × 10^{-23} Joule/K.
T	Absolute temperature (K) of a blackbody.
λ	Wavelength (μm).

➲ The factor 10^{-6} is used since spectral emittance in the curves is expressed in Watt/m^2, μm.

Planck's formula, when plotted graphically for various temperatures, produces a family of curves. Following any particular Planck curve, the spectral emittance is zero at λ = 0, then increases rapidly to a maximum at a wavelength λ_{max} and after passing it approaches zero again at very long wavelengths. The higher the temperature, the shorter the wavelength at which maximum occurs.

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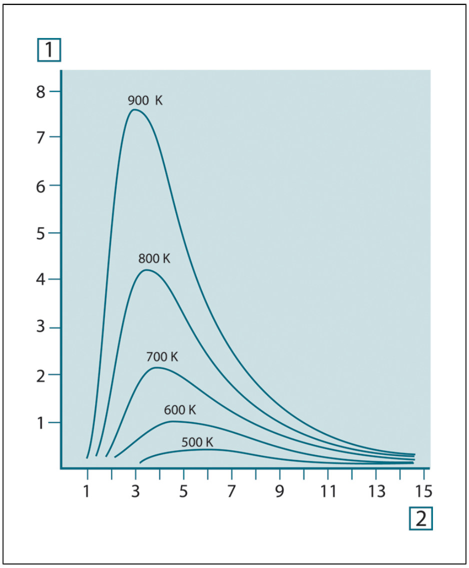

Figure 16.4 Blackbody spectral radiant emittance according to Planck's law, plotted for various absolute temperatures. **1:** Spectral radiant emittance (W/cm^2 × 10^3(μm)); **2:** Wavelength (μm)

16.3.2 Wien's displacement law

By differentiating Planck's formula with respect to λ, and finding the maximum, we have:

$$\lambda_{\max} = \frac{2898}{T}[\mu m]$$

This is Wien's formula (after *Wilhelm Wien*, 1864–1928), which expresses mathematically the common observation that colors vary from red to orange or yellow as the temperature of a thermal radiator increases. The wavelength of the color is the same as the wavelength calculated for λ_{max}. A good approximation of the value of λ_{max} for a given blackbody temperature is obtained by applying the rule-of-thumb 3 000/T

µm. Thus, a very hot star such as Sirius (11 000 K), emitting bluish-white light, radiates with the peak of spectral radiant emittance occurring within the invisible ultraviolet spectrum, at wavelength 0.27 µm.

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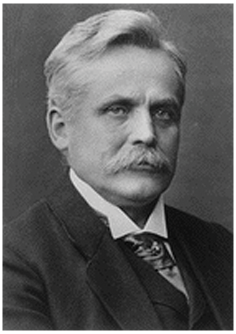

Figure 16.5 Wilhelm Wien (1864–1928)

The sun (approx. 6 000 K) emits yellow light, peaking at about 0.5 µm in the middle of the visible light spectrum.

At room temperature (300 K) the peak of radiant emittance lies at 9.7 µm, in the far infrared, while at the temperature of liquid nitrogen (77 K) the maximum of the almost insignificant amount of radiant emittance occurs at 38 µm, in the extreme infrared wavelengths.

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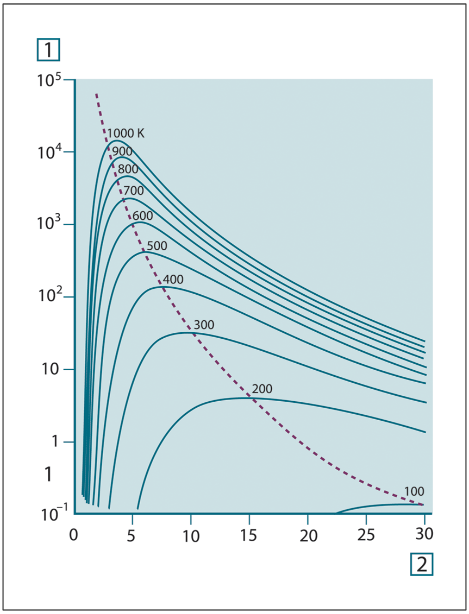

Figure 16.6 Planckian curves plotted on semi-log scales from 100 K to 1000 K. The dotted line represents the locus of maximum radiant emittance at each temperature as described by Wien's displacement law. **1:** Spectral radiant emittance (W/cm² (μm)); **2:** Wavelength (μm).

16.3.3 Stefan-Boltzmann's law

By integrating Planck's formula from λ = 0 to λ = ∞, we obtain the total radiant emittance (W_b) of a blackbody:

$$W_b = \sigma T^4 \ [\mathrm{Watt/m^2}]$$

This is the Stefan-Boltzmann formula (after *Josef Stefan*, 1835–1893, and *Ludwig Boltzmann*, 1844–1906), which states that the total emissive power of a blackbody is proportional to the fourth power of its absolute temperature. Graphically, W_b represents the area below the Planck curve for a particular temperature. It can be shown that the radiant emittance in the interval λ = 0 to λ_{max} is only 25% of the total, which represents about the amount of the sun's radiation which lies inside the visible light spectrum.

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Figure 16.7 Josef Stefan (1835–1893), and Ludwig Boltzmann (1844–1906)

Using the Stefan-Boltzmann formula to calculate the power radiated by the human body, at a temperature of 300 K and an external surface area of approx. 2 m^2, we obtain 1 kW. This power loss could not be sustained if it were not for the compensating absorption of radiation from surrounding surfaces, at room temperatures which do not vary too drastically from the temperature of the body – or, of course, the addition of clothing.

16.3.4 Non-blackbody emitters

So far, only blackbody radiators and blackbody radiation have been discussed. However, real objects almost never comply with these laws over an extended wavelength region – although they may approach the blackbody behavior in certain spectral intervals. For example, a certain type of white paint may appear perfectly *white* in the visible light spectrum, but becomes distinctly *gray* at about 2 µm, and beyond 3 µm it is almost *black*.

There are three processes which can occur that prevent a real object from acting like a blackbody: a fraction of the incident radiation α may be absorbed, a fraction ρ may be reflected, and a fraction τ may be transmitted. Since all of these factors are more or less wavelength dependent, the subscript λ is used to imply the spectral dependence of their definitions. Thus:

- The spectral absorptance α_λ= the ratio of the spectral radiant power absorbed by an object to that incident upon it.
- The spectral reflectance ρ_λ = the ratio of the spectral radiant power reflected by an object to that incident upon it.
- The spectral transmittance τ_λ = the ratio of the spectral radiant power transmitted through an object to that incident upon it.

The sum of these three factors must always add up to the whole at any wavelength, so we have the relation:

$$\alpha_\lambda + \rho_\lambda + \tau_\lambda = 1$$

For opaque materials $\tau_\lambda = 0$ and the relation simplifies to:

$$\alpha_\lambda + \rho_\lambda = 1$$

Another factor, called the emissivity, is required to describe the fraction ε of the radiant emittance of a blackbody produced by an object at a specific temperature. Thus, we have the definition:

The spectral emissivity ε_λ= the ratio of the spectral radiant power from an object to that from a blackbody at the same temperature and wavelength.

Expressed mathematically, this can be written as the ratio of the spectral emittance of the object to that of a blackbody as follows:

$$\varepsilon_\lambda = \frac{W_{\lambda o}}{W_{\lambda b}}$$

Generally speaking, there are three types of radiation source, distinguished by the ways in which the spectral emittance of each varies with wavelength.

- A blackbody, for which $\varepsilon_\lambda = \varepsilon = 1$
- A graybody, for which $\varepsilon_\lambda = \varepsilon$ = constant less than 1
- A selective radiator, for which ε varies with wavelength

According to Kirchhoff's law, for any material the spectral emissivity and spectral absorptance of a body are equal at any specified temperature and wavelength. That is:

$$\varepsilon_\lambda = \alpha_\lambda$$

From this we obtain, for an opaque material (since $\alpha_\lambda + \rho_\lambda = 1$):

$$\varepsilon_\lambda + \rho_\lambda = 1$$

For highly polished materials ε_λ approaches zero, so that for a perfectly reflecting material (*i.e.* a perfect mirror) we have:

$$\rho_\lambda = 1$$

For a graybody radiator, the Stefan-Boltzmann formula becomes:

$$W = \varepsilon\sigma T^4 \ [\mathrm{Watt/m^2}]$$

This states that the total emissive power of a graybody is the same as a blackbody at the same temperature reduced in proportion to the value of ε from the graybody.

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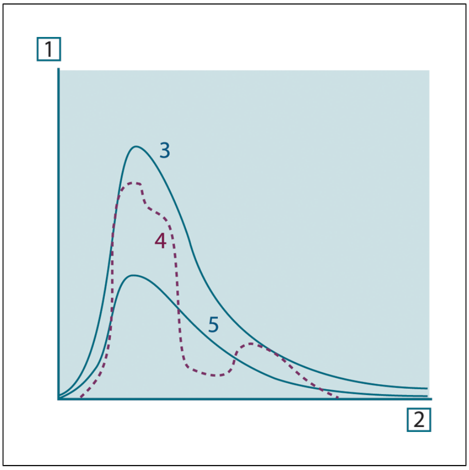

Figure 16.8 Spectral radiant emittance of three types of radiators. **1:** Spectral radiant emittance; **2:** Wavelength; **3:** Blackbody; **4:** Selective radiator; **5:** Graybody.

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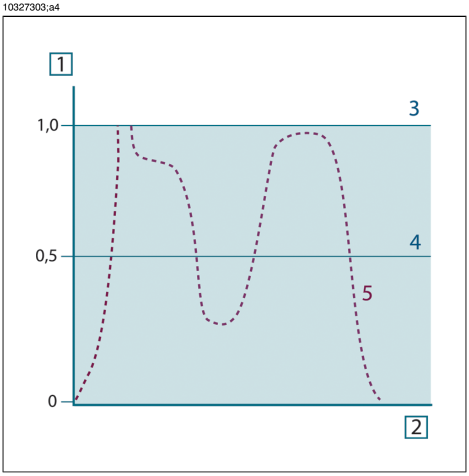

Figure 16.9 Spectral emissivity of three types of radiators. **1:** Spectral emissivity; **2:** Wavelength; **3:** Blackbody; **4:** Graybody; **5:** Selective radiator.

16.4 Infrared semi-transparent materials

Consider now a non-metallic, semi-transparent body – let us say, in the form of a thick flat plate of plastic material. When the plate is heated, radiation generated within its volume must work its way toward the surfaces through the material in which it is partially absorbed. Moreover, when it arrives at the surface, some of it is reflected back into the interior. The back-reflected radiation is again partially absorbed, but

some of it arrives at the other surface, through which most of it escapes; part of it is reflected back again. Although the progressive reflections become weaker and weaker they must all be added up when the total emittance of the plate is sought. When the resulting geometrical series is summed, the effective emissivity of a semi-transparent plate is obtained as:

$$\varepsilon_\lambda = \frac{(1-\rho_\lambda)(1-\tau_\lambda)}{1-\rho_\lambda\tau_\lambda}$$

When the plate becomes opaque this formula is reduced to the single formula:

$$\varepsilon_\lambda = 1-\rho_\lambda$$

This last relation is a particularly convenient one, because it is often easier to measure reflectance than to measure emissivity directly.

17 The measurement formula

As already mentioned, when viewing an object, the camera receives radiation not only from the object itself. It also collects radiation from the surroundings reflected via the object surface. Both these radiation contributions become attenuated to some extent by the atmosphere in the measurement path. To this comes a third radiation contribution from the atmosphere itself.

This description of the measurement situation, as illustrated in the figure below, is so far a fairly true description of the real conditions. What has been neglected could for instance be sun light scattering in the atmosphere or stray radiation from intense radiation sources outside the field of view. Such disturbances are difficult to quantify, however, in most cases they are fortunately small enough to be neglected. In case they are not negligible, the measurement configuration is likely to be such that the risk for disturbance is obvious, at least to a trained operator. It is then his responsibility to modify the measurement situation to avoid the disturbance e.g. by changing the viewing direction, shielding off intense radiation sources etc.

Accepting the description above, we can use the figure below to derive a formula for the calculation of the object temperature from the calibrated camera output.

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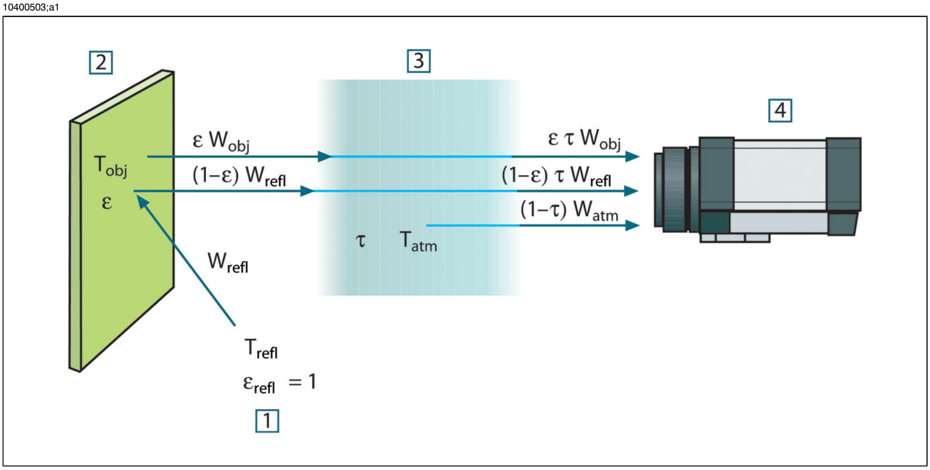

Figure 17.1 A schematic representation of the general thermographic measurement situation.**1:** Surroundings; **2:** Object; **3:** Atmosphere; **4:** Camera

Assume that the received radiation power W from a blackbody source of temperature T_{source} on short distance generates a camera output signal U_{source} that is proportional to the power input (power linear camera). We can then write (Equation 1):

$$U_{source} = CW(T_{source})$$

or, with simplified notation:

$$U_{source} = CW_{source}$$

where C is a constant.

Should the source be a graybody with emittance ε, the received radiation would consequently be εW_{source}.

We are now ready to write the three collected radiation power terms:

1 – Emission from the object = $\varepsilon\tau W_{obj}$, where ε is the emittance of the object and τ is the transmittance of the atmosphere. The object temperature is T_{obj}.

2 – Reflected emission from ambient sources = $(1 – \varepsilon)\tau W_{refl}$, where $(1 – \varepsilon)$ is the reflectance of the object. The ambient sources have the temperature T_{refl}.

It has here been assumed that the temperature T_{refl} is the same for all emitting surfaces within the halfsphere seen from a point on the object surface. This is of course sometimes a simplification of the true situation. It is, however, a necessary simplification in order to derive a workable formula, and T_{refl} can – at least theoretically – be given a value that represents an efficient temperature of a complex surrounding.

Note also that we have assumed that the emittance for the surroundings = 1. This is correct in accordance with Kirchhoff's law: All radiation impinging on the surrounding surfaces will eventually be absorbed by the same surfaces. Thus the emittance = 1. (Note though that the latest discussion requires the complete sphere around the object to be considered.)

3 – Emission from the atmosphere = $(1 – \tau)\tau W_{atm}$, where $(1 – \tau)$ is the emittance of the atmosphere. The temperature of the atmosphere is T_{atm}.

The total received radiation power can now be written (Equation 2):

$$W_{tot} = \varepsilon\tau W_{obj} + (1-\varepsilon)\tau W_{refl} + (1-\tau)W_{atm}$$

We multiply each term by the constant C of Equation 1 and replace the CW products by the corresponding U according to the same equation, and get (Equation 3):

$$U_{tot} = \varepsilon\tau U_{obj} + (1-\varepsilon)\tau U_{refl} + (1-\tau)U_{atm}$$

Solve Equation 3 for U_{obj} (Equation 4):

$$U_{obj} = \frac{1}{\varepsilon\tau}U_{tot} - \frac{1-\varepsilon}{\varepsilon}U_{refl} - \frac{1-\tau}{\varepsilon\tau}U_{atm}$$

This is the general measurement formula used in all the FLIR Systems thermographic equipment. The voltages of the formula are:

Figure 17.2 Voltages

U_{obj}	Calculated camera output voltage for a blackbody of temperature T_{obj} i.e. a voltage that can be directly converted into true requested object temperature.
U_{tot}	Measured camera output voltage for the actual case.
U_{refl}	Theoretical camera output voltage for a blackbody of temperature T_{refl} according to the calibration.
U_{atm}	Theoretical camera output voltage for a blackbody of temperature T_{atm} according to the calibration.

The operator has to supply a number of parameter values for the calculation:

- the object emittance ε,
- the relative humidity,
- T_{atm}
- object distance (D_{obj})
- the (effective) temperature of the object surroundings, or the reflected ambient temperature T_{refl}, and
- the temperature of the atmosphere T_{atm}

This task could sometimes be a heavy burden for the operator since there are normally no easy ways to find accurate values of emittance and atmospheric transmittance for the actual case. The two temperatures are normally less of a problem provided the surroundings do not contain large and intense radiation sources.

A natural question in this connection is: How important is it to know the right values of these parameters? It could though be of interest to get a feeling for this problem already here by looking into some different measurement cases and compare the relative magnitudes of the three radiation terms. This will give indications about when it is important to use correct values of which parameters.

The figures below illustrates the relative magnitudes of the three radiation contributions for three different object temperatures, two emittances, and two spectral ranges: SW and LW. Remaining parameters have the following fixed values:

- $\tau = 0.88$
- T_{refl} = +20°C (+68°F)
- T_{atm} = +20°C (+68°F)

It is obvious that measurement of low object temperatures are more critical than measuring high temperatures since the 'disturbing' radiation sources are relatively much stronger in the first case. Should also the object emittance be low, the situation would be still more difficult.

We have finally to answer a question about the importance of being allowed to use the calibration curve above the highest calibration point, what we call extrapolation. Imagine that we in a certain case measure $U_{tot} = 4.5$ volts. The highest calibration point for the camera was in the order of 4.1 volts, a value unknown to the operator. Thus, even if the object happened to be a blackbody, i.e. $U_{obj} = U_{tot}$, we are actually performing extrapolation of the calibration curve when converting 4.5 volts into temperature.

Let us now assume that the object is not black, it has an emittance of 0.75, and the transmittance is 0.92. We also assume that the two second terms of Equation 4 amount to 0.5 volts together. Computation of U_{obj} by means of Equation 4 then results in $U_{obj} = 4.5 / 0.75 / 0.92 - 0.5 = 6.0$. This is a rather extreme extrapolation, particularly when considering that the video amplifier might limit the output to 5 volts! Note, though, that the application of the calibration curve is a theoretical procedure where no electronic or other limitations exist. We trust that if there had been no signal limitations in the camera, and if it had been calibrated far beyond 5 volts, the resulting curve would have been very much the same as our real curve extrapolated beyond 4.1 volts, provided the calibration algorithm is based on radiation physics, like the FLIR Systems algorithm. Of course there must be a limit to such extrapolations.

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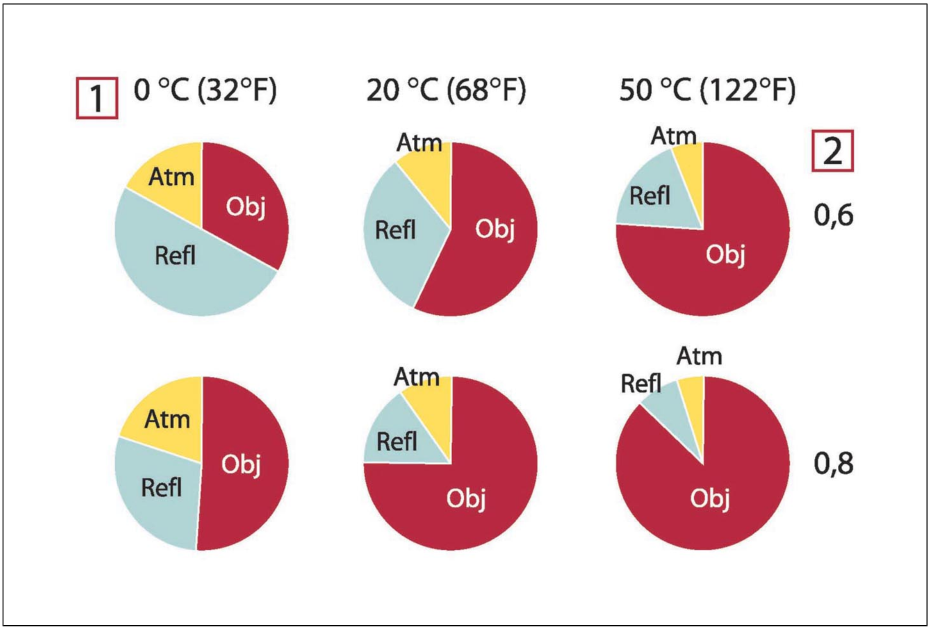

Figure 17.3 Relative magnitudes of radiation sources under varying measurement conditions (SW camera). **1:** Object temperature; **2:** Emittance; **Obj:** Object radiation; **Refl:** Reflected radiation; **Atm:** atmosphere radiation. Fixed parameters: $\tau = 0.88$; $T_{refl} = 20°C$ (+68°F); $T_{atm} = 20°C$ (+68°F).

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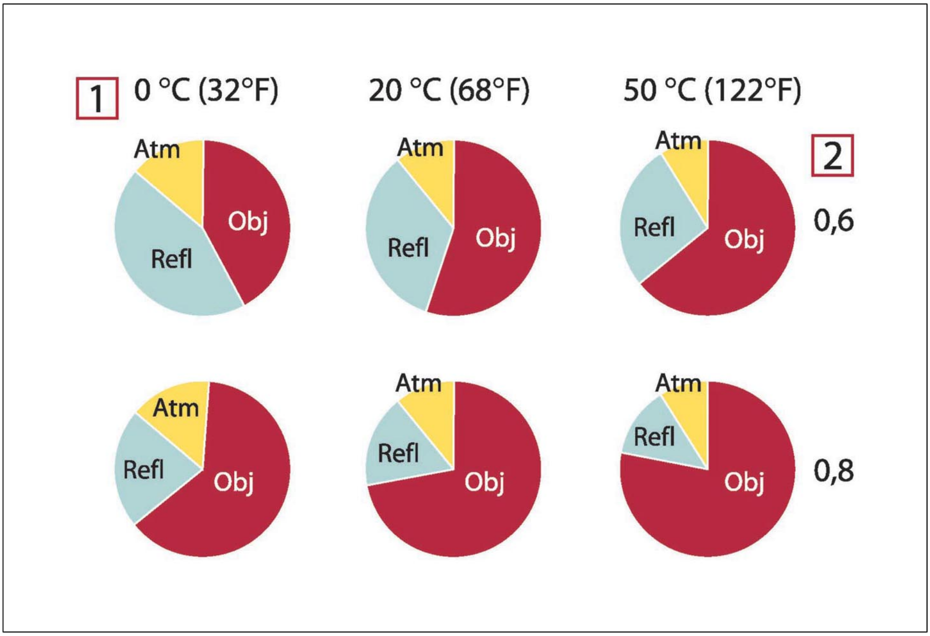

Figure 17.4 Relative magnitudes of radiation sources under varying measurement conditions (LW camera). **1:** Object temperature; **2:** Emittance; **Obj:** Object radiation; **Refl:** Reflected radiation; **Atm:** atmosphere radiation. Fixed parameters: $\tau = 0.88$; $T_{refl} = 20°C$ (+68°F); $T_{atm} = 20°C$ (+68°F).

18 Emissivity tables

This section presents a compilation of emissivity data from the infrared literature and measurements made by FLIR Systems.

18.1 References

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7	Vlcek, J: *Determination of emissivity with imaging radiometers and some emissivities at* $\lambda = 5\ \mu m$*.* Photogrammetric Engineering and Remote Sensing.
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9	Öhman, Claes: *Emittansmätningar med AGEMA E-Box*. Teknisk rapport, AGEMA 1999. (Emittance measurements using AGEMA E-Box. Technical report, AGEMA 1999.)
10	Matteï, S., Tang-Kwor, E: *Emissivity measurements for Nextel Velvet coating 811-21 between –36°C AND 82°C.*
11	Lohrengel & Todtenhaupt (1996)
12	ITC Technical publication 32.
13	ITC Technical publication 29.

18.2 Important note about the emissivity tables

The emissivity values in the table below are recorded using a shortwave (SW) camera. The values should be regarded as recommendations only and used by caution.

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18.3 Tables

Figure 18.1 **T:** Total spectrum; **SW:** 2–5 μm; **LW:** 8–14 μm, **LLW:** 6.5–20 μm; **1:** Material; **2:** Specification; **3:** Temperature in °C; **4:** Spectrum; **5:** Emissivity: **6:** Reference

1	2	3	4	5	6
3M type 35	Vinyl electrical tape (several colors)	< 80	LW	Ca. 0.96	13
3M type 88	Black vinyl electrical tape	< 105	LW	Ca. 0.96	13
3M type 88	Black vinyl electrical tape	< 105	MW	< 0.96	13
3M type Super 33+	Black vinyl electrical tape	< 80	LW	Ca. 0.96	13
Aluminum	anodized, black, dull	70	LW	0.95	9
Aluminum	anodized, black, dull	70	SW	0.67	9
Aluminum	anodized, light gray, dull	70	LW	0.97	9
Aluminum	anodized, light gray, dull	70	SW	0.61	9
Aluminum	anodized sheet	100	T	0.55	2
Aluminum	as received, plate	100	T	0.09	4
Aluminum	as received, sheet	100	T	0.09	2
Aluminum	cast, blast cleaned	70	LW	0.46	9
Aluminum	cast, blast cleaned	70	SW	0.47	9
Aluminum	dipped in HNO_3, plate	100	T	0.05	4
Aluminum	foil	27	3 μm	0.09	3
Aluminum	foil	27	10 μm	0.04	3
Aluminum	oxidized, strongly	50–500	T	0.2–0.3	1
Aluminum	polished	50–100	T	0.04–0.06	1
Aluminum	polished, sheet	100	T	0.05	2
Aluminum	polished plate	100	T	0.05	4

1	2	3	4	5	6
Aluminum	roughened	27	3 μm	0.28	3
Aluminum	roughened	27	10 μm	0.18	3
Aluminum	rough surface	20–50	T	0.06–0.07	1
Aluminum	sheet, 4 samples differently scratched	70	LW	0.03–0.06	9
Aluminum	sheet, 4 samples differently scratched	70	SW	0.05–0.08	9
Aluminum	vacuum deposited	20	T	0.04	2
Aluminum	weathered, heavily	17	SW	0.83–0.94	5
Aluminum bronze		20	T	0.60	1
Aluminum hydroxide	powder		T	0.28	1
Aluminum oxide	activated, powder		T	0.46	1
Aluminum oxide	pure, powder (alumina)		T	0.16	1
Asbestos	board	20	T	0.96	1
Asbestos	fabric		T	0.78	1
Asbestos	floor tile	35	SW	0.94	7
Asbestos	paper	40–400	T	0.93–0.95	1
Asbestos	powder		T	0.40–0.60	1
Asbestos	slate	20	T	0.96	1
Asphalt paving		4	LLW	0.967	8
Brass	dull, tarnished	20–350	T	0.22	1
Brass	oxidized	70	SW	0.04–0.09	9
Brass	oxidized	70	LW	0.03–0.07	9
Brass	oxidized	100	T	0.61	2
Brass	oxidized at 600°C	200–600	T	0.59–0.61	1
Brass	polished	200	T	0.03	1
Brass	polished, highly	100	T	0.03	2

1	2	3	4	5	6
Brass	rubbed with 80-grit emery	20	T	0.20	2
Brass	sheet, rolled	20	T	0.06	1
Brass	sheet, worked with emery	20	T	0.2	1
Brick	alumina	17	SW	0.68	5
Brick	common	17	SW	0.86–0.81	5
Brick	Dinas silica, glazed, rough	1100	T	0.85	1
Brick	Dinas silica, refractory	1000	T	0.66	1
Brick	Dinas silica, unglazed, rough	1000	T	0.80	1
Brick	firebrick	17	SW	0.68	5
Brick	fireclay	20	T	0.85	1
Brick	fireclay	1000	T	0.75	1
Brick	fireclay	1200	T	0.59	1
Brick	masonry	35	SW	0.94	7
Brick	masonry, plastered	20	T	0.94	1
Brick	red, common	20	T	0.93	2
Brick	red, rough	20	T	0.88–0.93	1
Brick	refractory, corundum	1000	T	0.46	1
Brick	refractory, magnesite	1000–1300	T	0.38	1
Brick	refractory, strongly radiating	500–1000	T	0.8–0.9	1
Brick	refractory, weakly radiating	500–1000	T	0.65–0.75	1
Brick	silica, 95% SiO_2	1230	T	0.66	1
Brick	sillimanite, 33% SiO_2, 64% Al_2O_3	1500	T	0.29	1

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1	2	3	4	5	6
Brick	waterproof	17	SW	0.87	5
Bronze	phosphor bronze	70	LW	0.06	9
Bronze	phosphor bronze	70	SW	0.08	9
Bronze	polished	50	T	0.1	1
Bronze	porous, rough	50–150	T	0.55	1
Bronze	powder		T	0.76–0.80	1
Carbon	candle soot	20	T	0.95	2
Carbon	charcoal powder		T	0.96	1
Carbon	graphite, filed surface	20	T	0.98	2
Carbon	graphite powder		T	0.97	1
Carbon	lampblack	20–400	T	0.95–0.97	1
Chipboard	untreated	20	SW	0.90	6
Chromium	polished	50	T	0.10	1
Chromium	polished	500–1000	T	0.28–0.38	1
Clay	fired	70	T	0.91	1
Cloth	black	20	T	0.98	1
Concrete		20	T	0.92	2
Concrete	dry	36	SW	0.95	7
Concrete	rough	17	SW	0.97	5
Concrete	walkway	5	LLW	0.974	8
Copper	commercial, burnished	20	T	0.07	1
Copper	electrolytic, carefully polished	80	T	0.018	1
Copper	electrolytic, polished	–34	T	0.006	4
Copper	molten	1100–1300	T	0.13–0.15	1
Copper	oxidized	50	T	0.6–0.7	1
Copper	oxidized, black	27	T	0.78	4

1	2	3	4	5	6
Copper	oxidized, heavily	20	T	0.78	2
Copper	oxidized to black-ness		T	0.88	1
Copper	polished	50–100	T	0.02	1
Copper	polished	100	T	0.03	2
Copper	polished, commer-cial	27	T	0.03	4
Copper	polished, mechan-ical	22	T	0.015	4
Copper	pure, carefully prepared surface	22	T	0.008	4
Copper	scraped	27	T	0.07	4
Copper dioxide	powder		T	0.84	1
Copper oxide	red, powder		T	0.70	1
Ebonite			T	0.89	1
Emery	coarse	80	T	0.85	1
Enamel		20	T	0.9	1
Enamel	lacquer	20	T	0.85–0.95	1
Fiber board	hard, untreated	20	SW	0.85	6
Fiber board	masonite	70	LW	0.88	9
Fiber board	masonite	70	SW	0.75	9
Fiber board	particle board	70	LW	0.89	9
Fiber board	particle board	70	SW	0.77	9
Fiber board	porous, untreated	20	SW	0.85	6
Gold	polished	130	T	0.018	1
Gold	polished, carefully	200–600	T	0.02–0.03	1
Gold	polished, highly	100	T	0.02	2
Granite	polished	20	LLW	0.849	8
Granite	rough	21	LLW	0.879	8
Granite	rough, 4 different samples	70	LW	0.77–0.87	9

1	2	3	4	5	6
Granite	rough, 4 different samples	70	SW	0.95–0.97	9
Gypsum		20	T	0.8–0.9	1
Ice: See Water					
Iron, cast	casting	50	T	0.81	1
Iron, cast	ingots	1000	T	0.95	1
Iron, cast	liquid	1300	T	0.28	1
Iron, cast	machined	800–1000	T	0.60–0.70	1
Iron, cast	oxidized	38	T	0.63	4
Iron, cast	oxidized	100	T	0.64	2
Iron, cast	oxidized	260	T	0.66	4
Iron, cast	oxidized	538	T	0.76	4
Iron, cast	oxidized at 600°C	200–600	T	0.64–0.78	1
Iron, cast	polished	38	T	0.21	4
Iron, cast	polished	40	T	0.21	2
Iron, cast	polished	200	T	0.21	1
Iron, cast	unworked	900–1100	T	0.87–0.95	1
Iron and steel	cold rolled	70	LW	0.09	9
Iron and steel	cold rolled	70	SW	0.20	9
Iron and steel	covered with red rust	20	T	0.61–0.85	1
Iron and steel	electrolytic	22	T	0.05	4
Iron and steel	electrolytic	100	T	0.05	4
Iron and steel	electrolytic	260	T	0.07	4
Iron and steel	electrolytic, carefully polished	175–225	T	0.05–0.06	1
Iron and steel	freshly worked with emery	20	T	0.24	1
Iron and steel	ground sheet	950–1100	T	0.55–0.61	1
Iron and steel	heavily rusted sheet	20	T	0.69	2

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1	2	3	4	5	6
Iron and steel	hot rolled	20	T	0.77	1
Iron and steel	hot rolled	130	T	0.60	1
Iron and steel	oxidized	100	T	0.74	1
Iron and steel	oxidized	100	T	0.74	4
Iron and steel	oxidized	125–525	T	0.78–0.82	1
Iron and steel	oxidized	200	T	0.79	2
Iron and steel	oxidized	1227	T	0.89	4
Iron and steel	oxidized	200–600	T	0.80	1
Iron and steel	oxidized strongly	50	T	0.88	1
Iron and steel	oxidized strongly	500	T	0.98	1
Iron and steel	polished	100	T	0.07	2
Iron and steel	polished	400–1000	T	0.14–0.38	1
Iron and steel	polished sheet	750–1050	T	0.52–0.56	1
Iron and steel	rolled, freshly	20	T	0.24	1
Iron and steel	rolled sheet	50	T	0.56	1
Iron and steel	rough, plane surface	50	T	0.95–0.98	1
Iron and steel	rusted, heavily	17	SW	0.96	5
Iron and steel	rusted red, sheet	22	T	0.69	4
Iron and steel	rusty, red	20	T	0.69	1
Iron and steel	shiny, etched	150	T	0.16	1
Iron and steel	shiny oxide layer, sheet,	20	T	0.82	1
Iron and steel	wrought, carefully polished	40–250	T	0.28	1
Iron galvanized	heavily oxidized	70	LW	0.85	9
Iron galvanized	heavily oxidized	70	SW	0.64	9
Iron galvanized	sheet	92	T	0.07	4
Iron galvanized	sheet, burnished	30	T	0.23	1
Iron galvanized	sheet, oxidized	20	T	0.28	1

1	2	3	4	5	6
Iron tinned	sheet	24	T	0.064	4
Krylon Ultra-flat black 1602	Flat black	Room temperature up to 175	LW	Ca. 0.96	12
Krylon Ultra-flat black 1602	Flat black	Room temperature up to 175	MW	Ca. 0.97	12
Lacquer	3 colors sprayed on Aluminum	70	LW	0.92–0.94	9
Lacquer	3 colors sprayed on Aluminum	70	SW	0.50–0.53	9
Lacquer	Aluminum on rough surface	20	T	0.4	1
Lacquer	bakelite	80	T	0.83	1
Lacquer	black, dull	40–100	T	0.96–0.98	1
Lacquer	black, matte	100	T	0.97	2
Lacquer	black, shiny, sprayed on iron	20	T	0.87	1
Lacquer	heat–resistant	100	T	0.92	1
Lacquer	white	40–100	T	0.8–0.95	1
Lacquer	white	100	T	0.92	2
Lead	oxidized, gray	20	T	0.28	1
Lead	oxidized, gray	22	T	0.28	4
Lead	oxidized at 200°C	200	T	0.63	1
Lead	shiny	250	T	0.08	1
Lead	unoxidized, polished	100	T	0.05	4
Lead red		100	T	0.93	4
Lead red, powder		100	T	0.93	1
Leather	tanned		T	0.75–0.80	1
Lime			T	0.3–0.4	1
Magnesium		22	T	0.07	4
Magnesium		260	T	0.13	4

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1	2	3	4	5	6
Magnesium		538	T	0.18	4
Magnesium	polished	20	T	0.07	2
Magnesium powder			T	0.86	1
Molybdenum		600–1000	T	0.08–0.13	1
Molybdenum		1500–2200	T	0.19–0.26	1
Molybdenum	filament	700–2500	T	0.1–0.3	1
Mortar		17	SW	0.87	5
Mortar	dry	36	SW	0.94	7
Nextel Velvet 811-21 Black	Flat black	–60–150	LW	> 0.97	10 and 11
Nichrome	rolled	700	T	0.25	1
Nichrome	sandblasted	700	T	0.70	1
Nichrome	wire, clean	50	T	0.65	1
Nichrome	wire, clean	500–1000	T	0.71–0.79	1
Nichrome	wire, oxidized	50–500	T	0.95–0.98	1
Nickel	bright matte	122	T	0.041	4
Nickel	commercially pure, polished	100	T	0.045	1
Nickel	commercially pure, polished	200–400	T	0.07–0.09	1
Nickel	electrolytic	22	T	0.04	4
Nickel	electrolytic	38	T	0.06	4
Nickel	electrolytic	260	T	0.07	4
Nickel	electrolytic	538	T	0.10	4
Nickel	electroplated, polished	20	T	0.05	2
Nickel	electroplated on iron, polished	22	T	0.045	4
Nickel	electroplated on iron, unpolished	20	T	0.11–0.40	1

1	2	3	4	5	6
Nickel	electroplated on iron, unpolished	22	T	0.11	4
Nickel	oxidized	200	T	0.37	2
Nickel	oxidized	227	T	0.37	4
Nickel	oxidized	1227	T	0.85	4
Nickel	oxidized at 600°C	200–600	T	0.37–0.48	1
Nickel	polished	122	T	0.045	4
Nickel	wire	200–1000	T	0.1–0.2	1
Nickel oxide		500–650	T	0.52–0.59	1
Nickel oxide		1000–1250	T	0.75–0.86	1
Oil, lubricating	0.025 mm film	20	T	0.27	2
Oil, lubricating	0.050 mm film	20	T	0.46	2
Oil, lubricating	0.125 mm film	20	T	0.72	2
Oil, lubricating	film on Ni base: Ni base only	20	T	0.05	2
Oil, lubricating	thick coating	20	T	0.82	2
Paint	8 different colors and qualities	70	LW	0.92–0.94	9
Paint	8 different colors and qualities	70	SW	0.88–0.96	9
Paint	Aluminum, various ages	50–100	T	0.27–0.67	1
Paint	cadmium yellow		T	0.28–0.33	1
Paint	chrome green		T	0.65–0.70	1
Paint	cobalt blue		T	0.7–0.8	1
Paint	oil	17	SW	0.87	5
Paint	oil, black flat	20	SW	0.94	6
Paint	oil, black gloss	20	SW	0.92	6
Paint	oil, gray flat	20	SW	0.97	6
Paint	oil, gray gloss	20	SW	0.96	6
Paint	oil, various colors	100	T	0.92–0.96	1

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1	2	3	4	5	6
Paint	oil based, average of 16 colors	100	T	0.94	2
Paint	plastic, black	20	SW	0.95	6
Paint	plastic, white	20	SW	0.84	6
Paper	4 different colors	70	LW	0.92–0.94	9
Paper	4 different colors	70	SW	0.68–0.74	9
Paper	black		T	0.90	1
Paper	black, dull		T	0.94	1
Paper	black, dull	70	LW	0.89	9
Paper	black, dull	70	SW	0.86	9
Paper	blue, dark		T	0.84	1
Paper	coated with black lacquer		T	0.93	1
Paper	green		T	0.85	1
Paper	red		T	0.76	1
Paper	white	20	T	0.7–0.9	1
Paper	white, 3 different glosses	70	LW	0.88–0.90	9
Paper	white, 3 different glosses	70	SW	0.76–0.78	9
Paper	white bond	20	T	0.93	2
Paper	yellow		T	0.72	1
Plaster		17	SW	0.86	5
Plaster	plasterboard, untreated	20	SW	0.90	6
Plaster	rough coat	20	T	0.91	2
Plastic	glass fibre laminate (printed circ. board)	70	LW	0.91	9
Plastic	glass fibre laminate (printed circ. board)	70	SW	0.94	9

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1	2	3	4	5	6
Plastic	polyurethane isolation board	70	LW	0.55	9
Plastic	polyurethane isolation board	70	SW	0.29	9
Plastic	PVC, plastic floor, dull, structured	70	LW	0.93	9
Plastic	PVC, plastic floor, dull, structured	70	SW	0.94	9
Platinum		17	T	0.016	4
Platinum		22	T	0.03	4
Platinum		100	T	0.05	4
Platinum		260	T	0.06	4
Platinum		538	T	0.10	4
Platinum		1000–1500	T	0.14–0.18	1
Platinum		1094	T	0.18	4
Platinum	pure, polished	200–600	T	0.05–0.10	1
Platinum	ribbon	900–1100	T	0.12–0.17	1
Platinum	wire	50–200	T	0.06–0.07	1
Platinum	wire	500–1000	T	0.10–0.16	1
Platinum	wire	1400	T	0.18	1
Porcelain	glazed	20	T	0.92	1
Porcelain	white, shiny		T	0.70–0.75	1
Rubber	hard	20	T	0.95	1
Rubber	soft, gray, rough	20	T	0.95	1
Sand			T	0.60	1
Sand		20	T	0.90	2
Sandstone	polished	19	LLW	0.909	8
Sandstone	rough	19	LLW	0.935	8
Silver	polished	100	T	0.03	2
Silver	pure, polished	200–600	T	0.02–0.03	1

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1	2	3	4	5	6
Skin	human	32	T	0.98	2
Slag	boiler	0–100	T	0.97–0.93	1
Slag	boiler	200–500	T	0.89–0.78	1
Slag	boiler	600–1200	T	0.76–0.70	1
Slag	boiler	1400–1800	T	0.69–0.67	1
Snow: See Water					
Soil	dry	20	T	0.92	2
Soil	saturated with water	20	T	0.95	2
Stainless steel	alloy, 8% Ni, 18% Cr	500	T	0.35	1
Stainless steel	rolled	700	T	0.45	1
Stainless steel	sandblasted	700	T	0.70	1
Stainless steel	sheet, polished	70	LW	0.14	9
Stainless steel	sheet, polished	70	SW	0.18	9
Stainless steel	sheet, untreated, somewhat scratched	70	LW	0.28	9
Stainless steel	sheet, untreated, somewhat scratched	70	SW	0.30	9
Stainless steel	type 18-8, buffed	20	T	0.16	2
Stainless steel	type 18-8, oxidized at 800°C	60	T	0.85	2
Stucco	rough, lime	10–90	T	0.91	1
Styrofoam	insulation	37	SW	0.60	7
Tar			T	0.79–0.84	1
Tar	paper	20	T	0.91–0.93	1
Tile	glazed	17	SW	0.94	5
Tin	burnished	20–50	T	0.04–0.06	1
Tin	tin–plated sheet iron	100	T	0.07	2

1	2	3	4	5	6
Titanium	oxidized at 540°C	200	T	0.40	1
Titanium	oxidized at 540°C	500	T	0.50	1
Titanium	oxidized at 540°C	1000	T	0.60	1
Titanium	polished	200	T	0.15	1
Titanium	polished	500	T	0.20	1
Titanium	polished	1000	T	0.36	1
Tungsten		200	T	0.05	1
Tungsten		600–1000	T	0.1–0.16	1
Tungsten		1500–2200	T	0.24–0.31	1
Tungsten	filament	3300	T	0.39	1
Varnish	flat	20	SW	0.93	6
Varnish	on oak parquet floor	70	LW	0.90–0.93	9
Varnish	on oak parquet floor	70	SW	0.90	9
Wallpaper	slight pattern, light gray	20	SW	0.85	6
Wallpaper	slight pattern, red	20	SW	0.90	6
Water	distilled	20	T	0.96	2
Water	frost crystals	–10	T	0.98	2
Water	ice, covered with heavy frost	0	T	0.98	1
Water	ice, smooth	–10	T	0.96	2
Water	ice, smooth	0	T	0.97	1
Water	layer >0.1 mm thick	0–100	T	0.95–0.98	1
Water	snow		T	0.8	1
Water	snow	–10	T	0.85	2
Wood		17	SW	0.98	5
Wood		19	LLW	0.962	8
Wood	ground		T	0.5–0.7	1

1	2	3	4	5	6
Wood	pine, 4 different samples	70	LW	0.81–0.89	9
Wood	pine, 4 different samples	70	SW	0.67–0.75	9
Wood	planed	20	T	0.8–0.9	1
Wood	planed oak	20	T	0.90	2
Wood	planed oak	70	LW	0.88	9
Wood	planed oak	70	SW	0.77	9
Wood	plywood, smooth, dry	36	SW	0.82	7
Wood	plywood, untreat-ed	20	SW	0.83	6
Wood	white, damp	20	T	0.7–0.8	1
Zinc	oxidized at 400°C	400	T	0.11	1
Zinc	oxidized surface	1000–1200	T	0.50–0.60	1
Zinc	polished	200–300	T	0.04–0.05	1
Zinc	sheet	50	T	0.20	1

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A note on the technical production of this publication

This publication was produced using XML—the *eXtensible Markup Language*. For more information about XML, please visit http://www.w3.org/XML/

A note on the typeface used in this publication

This publication was typeset using Swiss 721, which is Bitstream's pan-European version of the Helvetica™ typeface. Helvetica™ was designed by Max Miedinger (1910–1980).

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